INSTRUCTION MANUAL

MODEL 4200
RF MICROWATTMETER

This manual applies to
serial numbers 890 and below.

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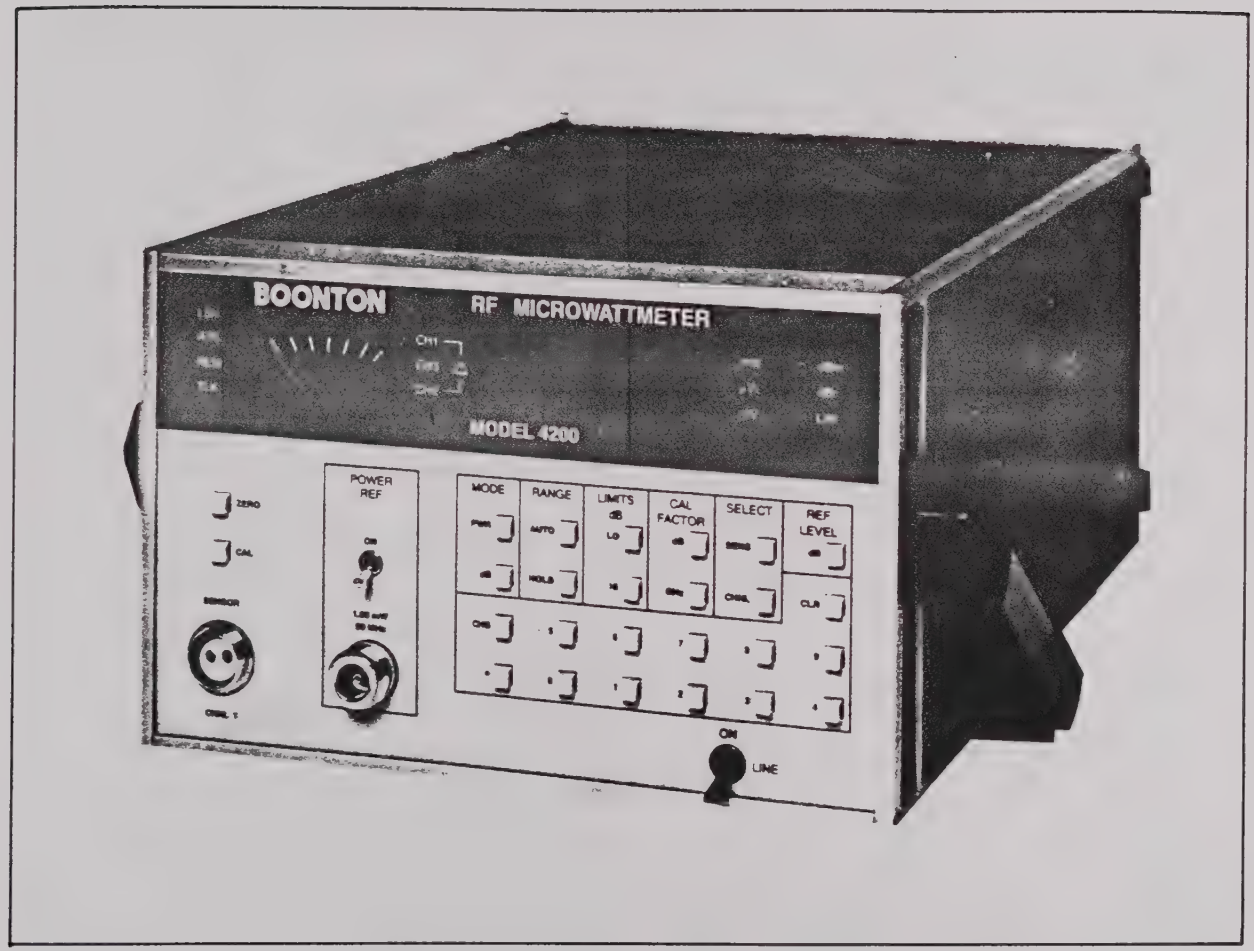


Figure 1-1 Model 4200 RF Microwattmeter

SECTION I
INTRODUCTION

1-1. SCOPE OF MANUAL.

1-2. This instruction manual provides descriptive data, operating instructions, theory of operation, maintenance instructions, and a parts list for the Model 4200 RF Microwattmeter. (See Figure 4-1.) The instrument is manufactured by Boonton Electronics Corporation, Parsippany, New Jersey.

1-3. PURPOSE OF EQUIPMENT.

1-4. The instrument is a microprocessor-controlled, solid-state unit that features ease of operation, high sensitivity, low input SWR, and low noise. It measures RF power levels from 1 nW (-60 dBm) to 100 mW (+20 dBm). The calibrated frequency range extends from 0.2 MHz to 18 GHz, depending upon the accessory sensor used; useful response for relative measurements is obtained from 20 kHz to approximately 20 GHz. Representative uses of the instrument include:

a. Low-power transmitter, signal generator, and oscillator measurements

b. SWR and return-loss measurements with directional couplers and slotted lines

c. Gain and insertion loss measurements

d. RF attenuation and SWR measurements

e. Antenna measurements

1-5. DESCRIPTION OF EQUIPMENT.

1-6. The instrument is packaged as a compact bench unit with an optional adjustable-angle bail. Hardware kits to accommodate either one or two instruments for rack mounting are also available as options. When operated with Boonton Series 4200 sensors, the instrument displays RF power by measuring the voltage across a precision, non-inductive resistor in the sensor head with specially selected diodes. Panel indications are calibrated in terms of power according to the relationship $P = E^2/R$. This detection system has important performance advantages over power meters that use bolometer or thermoelectric-detection. The instrument sensitivity of 1 nanowatt (-60 dBm) is orders of magnitude better; temperature stability of better than 0.001 dB/°C supports this sensitivity; and burnout levels exceed 300 milliwatts.

1-7. Diode sensors are RMS responding for low power levels (below 10 microwatts for Series 4200-4 sensors and 100 microwatts for Series 4200-5 sensors). At these low power levels, the instrument measures and displays true average power for all types of waveforms. Above these levels, the instrument displays, by means of internal shaping, the true average power of CW signals. If the RF signal is gated or amplitude modulated, the indicated power will not be the true average power. The signal may be attenuated to bring it within the RMS region of measurement. Alternately, the instrument can be used with thermal sensor Model 4240; in this case, the instrument measures and displays true average power for all waveforms.

1-8. Among the outstanding design features are:

a. **Wide Frequency Range.** The calibrated frequency range of the instrument is determined by the sensor used with the instrument. The instrument is normally ordered with one or more of the following sensors:

Model	Frequency Range (Impedance)	Power Range
4200-4A	200 kHz to 7 GHz (50 ohms)	1 nW to 10 mW
4200-4B	200 kHz to 12.4 GHz (50 ohms)	1 nW to 10 mW
4200-4C	200 kHz to 1 GHz (75 ohms)	1 nW to 10 mW
4200-4E	200 kHz to 18 GHz (50 ohms)	1 nW to 10 mW
4200-5B	200 kHz to 12.4 GHz (50 ohms)	10 nW to 100 mW
4200-5E	200 kHz to 18 GHz (50 ohms)	10 nW to 100 mW
4240	10 MHz to 18 GHz (50 ohms)	1 μW to 10 mW

b. **Wide Power Range.** Depending on the selected sensor, the instrument will measure RF power from 1 nW up to 100 mW. Temporary overloads up to 300 mW with Series 4200-4 sensors and up to 2W with Series 4200-5 sensors will do no permanent harm to the instrument or the sensor. When measuring pulsed signals, the power indications are accurate up to 20 microwatts peak power (200 microwatts with Series 4200-5 sensors). External attenuators may be used to extend the measurement range of the instrument.

c. **Low Noise.** The instrument has been designed and constructed to minimize noise from all sources. The sensor cable is of a special low-noise design; vigorous flexing causes only momentary minor deflections on the most sensitive range of the instrument. The sensors are insensitive to shock and vibration; even sharp tapping on

the sensor barrel causes no visible deflection on any range. Internal signal amplification occurs at approximately 94 Hz, thereby reducing susceptibility to 50 or 60 Hz fields. A low-noise solid-state chopper is used.

d. **LED Display.** Measured power levels are displayed by a 4 digit, LED type readout with decimal points and minus sign. Annunciators associated with the LED display indicate the units of measurement. The result is a clear, unambiguous readout that minimizes the possibility of misinterpretation. The LED display is also used during data entry through the front-panel keyboard of the instrument to indicate keyed-in values.

e. **Analog Indications.** A front-panel analog meter provides relative power indications for peaking or nulling applications. A dc voltage proportional to the measured power level is available at a rear-panel connector for application to a recorder or other external device.

f. **Pushbutton Measurement Mode Selection.** A choice of measurement modes is available to the operator. Indications in terms of power or dBm can be selected by pressing the appropriate front-panel key switch. A dB reference level can be entered through the keyboard and a display mode selected to indicate power levels in dB, relative to a dB reference level.

g. **Automatic Ranging.** Autoranging under control of the microprocessor eliminates the need for manual ranging. Alternately, a measurement range can be retained for all measurements, if desired, by selecting the range hold mode. Applications of power levels that exceed the maximum or minimum measurement capability of the instrument (or range in the hold mode) results in an error indication on the LED display.

h. **Automatic Zeroing.** An automatic zeroing circuit eliminates the need for tedious, often inaccurate, manual zeroing. With zero input to the sensor, pressing a front-panel key switch directs the microprocessor to compute and store zero corrections for each range, and the instrument is thereafter corrected on each range in accordance with the stored data. This method is considerably simpler, faster, and more accurate than manual zeroing.

i. **Automatic Sensor Compensation.** Calibration factors for up to four sensors may be stored in the microprocessor. Calibration data is written into nonvolatile storage at the factory for sensors ordered with the instrument; calibration data may also be written into storage in the field. When the sensor being used and the measurement frequency are specified through front-panel keyboard entry, measurement values are corrected automatically with calibration factors. Alternately, the calibration factor in dB for a particular sensor being used may be entered through the keyboard, and the measurement values are then corrected automatically in accordance with the correction factor. Both power and dB values are corrected.

j. **Built-in Power Reference.** An accurate, 1.000 milliwatt, 50 MHz signal for instrument calibration is provided by a built-in power reference. Calibration is simply a matter of turning on the power reference, connecting the sensor to the power reference, and pressing a key switch; the calibration correction is computed automatically by the microprocessor. The calibration circuit has built-in protection against inadvertent key actuation when the sensor is not connected to the power reference; calibration correction is limited to approximately 3.5% from the original factory set value. Computed calibration corrections that exceed this range are rejected automatically, and the instrument returns to its previous sensitivity. If the instrument is supplied with a 75-ohm sensor (4200-4C), an adapter (P/N 950006) is also supplied. This adapter is used between the power reference and the sensor to convert the Type N power reference connector to a 75-ohm Type N. Before calibration, a 0.17 dB CAL FACTOR should be entered to compensate for the mismatch error that is introduced by the 75-ohm sensor.

k. **Pushbutton High/Low dB Limit Selection.** High/low dB limits may be entered through the front-panel keyboard. A front-panel annunciator indicates when measured dB levels are outside the preset limits. Signals are also activated at a rear-panel connector to provide remote indications of out-of-limit measurements.

l. **Solid-state Chopper.** Signal amplification in the instrument occurs at approximately 94 Hz. Input signals from the sensor are converted into a 94 Hz signal by a solid-state, low-level input modulator (chopper), which represents a distinct improvement over electromechanical choppers. Extended service life is assured through the elimination of contact wear, contamination, and other problems associated with electromechanical choppers.

m. **Signature Analysis Maintenance.** Connection facilities to permit signature analysis maintenance are incorporated. Digital circuit troubles can be localized rapidly and accurately using the signature analysis maintenance technique, thereby reducing instrument down-time. A diagnostic PROM (P/N 950004) is available from Boonton Electronics Corporation for signature analysis maintenance.

1-9. ACCESSORIES.

1-10. The basic instrument is supplied complete with power cord and sensor cable, but without a sensor. It is designed to operate with any Boonton Electronics Corporation Series 4200 or 4240 sensors, the characteristics of which are listed in Table 1-1. If sensors are ordered with the basic instrument, calibration data for these sensors are written into microprocessor memory before shipment of the instrument. Calibration data for other sensors (up to 4 total) may be written into memory in the field.

1-11. OPTIONS.

1-12. Several standard options are currently available. These options are:

Option No.	Description
-01	IEEE 488 bus interface
-03	Second channel input
-04	Rear input
-05	Swing tilt handle

NOTE

Instructions for field installation and use of options are included in the appendices to this manual.

1-13. Option -03 deserves individual mention. With this option, the instrument can be fitted with two power sensors. The instrument can then be programmed through front-panel keys to display the input to either sensor or, alternately, the difference in power between the two inputs, expressed in dB. This option makes the measurement of gain or insertion loss a simple task. The gain or loss is displayed directly with no need to monitor and control the leveling of the power source. This option also allows the simultaneous use of a 50 ohm power sensor and a 75 ohm power sensor, a high level power sensor and a sensitive power sensor, or a diode sensor and a thermoelectric power sensor.

1-14. Inquiries regarding special applications of the instrument to specific customer requirements are invited. Direct such inquiries to the Applications Engineering Department of Boonton Electronics Corporation.

1-15. SPECIFICATIONS.

1-16. Pertinent performance specifications for the instrument are listed in Table 1-1.

1-17. OUTLINE DIMENSIONS.

1-18. Outline dimensions of the instrument are shown in Figure 1-4.

TABLE 1-1. PERFORMANCE SPECIFICATIONS

Parameter	Specifications
FREQUENCY RANGE	Refer to Table 1-2.
POWER RANGE (Display calibrated in mW, μW, nW, dBm, and dB relative to arbitrary reference):	
With all Series 4200-4 sensors	70 dB dynamic range, with 7 full-scale ranges of -50, -40, -30, -20, -10, 0, and +10 dBm (10 nW to 10 mW)
With all Series 4200-5 sensors	70 dB dynamic range, with 7 full-scale ranges of -40, -30, -20, -10, 0, +10, and +20 dBm (100 nW to 100 mW)
With Model 4240 sensor	40 dB dynamic range, with 4 full-scale ranges of -20, -10, 0, and +10 dBm (10 μW to 10 mW)
RANGING	Autoranging plus HOLD on range

Parameter	Specifications
BASIC INSTRUMENTATION ACCURACY:*	
ZERO	Automatic, operated by front-panel switch
ZERO SET	±1% of full scale on most sensitive range; typically ±1 count on other ranges
ZERO DRIFT:	
With Series 4200-4 sensors	1 nW/hr maximum on nW range
With Series 4200-5 sensors	10 nW/hr maximum on 100 nW range
With 4240 sensor	1 μW/hr maximum on 10 μW range

	>10 nW (100 nW with 4200-5 sensors)	<10 nW (100 nW with 4200-5 sensors)	<10 μW (4240 sensor)
Watt Mode	± 1.2% rdg ± 1 digit	± 1.5% rdg ± 1.5% fs	± 1% rdg ± 3% fs
dB Modes**	$0.05\ dB \pm \frac{dB_{fs} - dB_{rdg}}{200}$	$\pm 0.1\ dB \pm \frac{dB_{fs} - dB_{rdg}}{20}$	$\pm 0.1\ dB \pm \frac{dB_{fs} - dB_{rdg}}{10}$

*Uncertainty included: instrumentation, sensor nonlinearity, range zero corrections, and noise.
**Except in Channel 3 operation with option -03 where accuracy statement must be multiplied by factor of two.

TABLE 1-1. PERFORMANCE SPECIFICATIONS (Cont.)

Parameter	Specifications
TEMPERATURE REFERENCE:	
21°C to 25°C	0 dB for instrument; 0 db for Series 4200-4, 4200-5, and 4240 sensors
18°C to 30°C	0 dB for instrument; ±0.1 dB for Series 4200-4, 4200-5, and 4240 sensors
10°C to 40°C	±0.2 dB for instrument; ±0.2 dB for Series 4200-4, 4200-5, and 4240 sensors
POWER REFERENCE:	
Source	Internal 50 MHz oscillator with Type N female connector on front panel
Power output	1.00 mW, factory set to ±0.7%, traceable to National Bureau of Standards
Accuracy	±1.2% worst case for one year (0°C to 55°C)
Calibration	Front panel key automatically calibrates instrument to power reference
CALIBRATION FACTOR	1.25 dB to -1.25 dB range in 0.01 dB steps, entered through front panel keys; alternatively, stored calibration factors are interpreted linearly and applied automatically to readings when frequency is entered through front panel keys; nine individual calibration factors for up to 4 power sensors are stored in non-volatile memory
WAVEFORM RESPONSE:	
With Series 4200-4 sensors	True average power to 20 μW; average power of sine wave above 20 μW
With Series 4200-5 sensors	True average power to 200 μW; average power of sine wave above 200 nW
With 4240 sensor	True average power

Parameter	Specifications
RESPONSE TIME:	See Figures 1-2 and 1-3.
RECORDER OUTPUT	
Watt mode	10 volts full scale proportional to indicated power over each range
dB mode	8 volts equivalent to 0dBm with sensitivity of 1 volt per 10 dB change over entire range
DISPLAY	4 digit LED: 3-1/2 digit display of power, 4 digit display of dB with 0.01 dB resolution
	Auxiliary analog display, uncalibrated, proportional to analog output
ANNUNCIATORS	LED display of mW, μW, nW, dBm, or relative dB (dBr); LED indication of use of channel 1 (CH 1), channel 2 (CH 2, option -03), channel 3 (CH 3 = CH 1 — CH 2 in dB), out of dB limits, and condition of IEEE-488 bus activity (LSN, ATN, REM, TLK, option -01)
POWER CONSUMPTION	24 VA, 100, 120, 220, 240 volts, 50 to 400 Hz
WEIGHT	Approximately 10 pounds (4.54 kg); battery option, 5 pounds (2.3 kg) additional
SIZE	8.3 inches (21.1 cm) wide, 5.85 inches (14.9 cm) high, 13.75 inches (34.9 cm) long
ACCESSORIES FURNISHED	5 foot power sensor cable, Model 41-2A

TABLE 1-1. PERFORMANCE SPECIFICATIONS (Cont.)

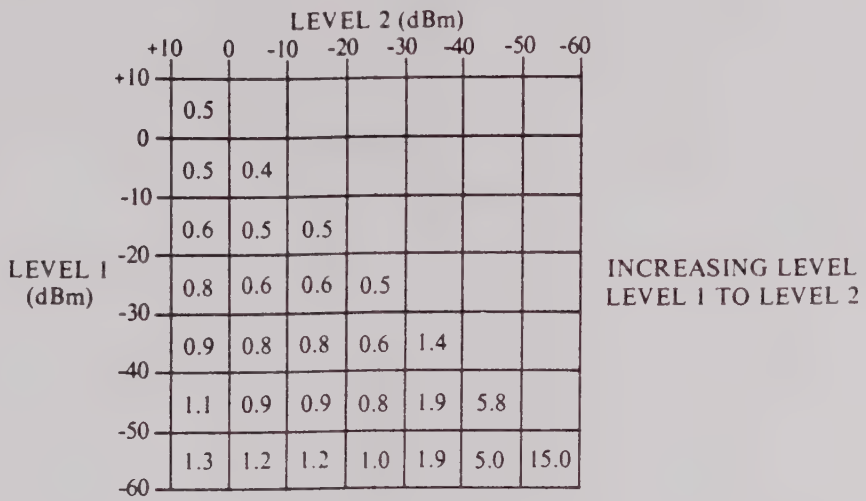
Parameter	Specifications	Parameter	Specifications
ACCESSORIES AVAILABLE:		OPTIONS:	
Part No. 950000	Rack mounts one Model 4200, placed either right or left on 19-inch spacing	-01	IEEE 488 bus interface
		-03	Input channel 2 (allows display of either channel 1 or channel 2, or channel 3 which is channel 1 minus channel 2, expressed in dB)
Part No. 950001	Rack mounts two instruments, side by side	-04	Rear input
		-05	Swing-tilt handle
OTHER ACCESSORIES REQUIRED	One or more of following power sensors: Model 4200-4A, 4200-4B, 4200-4C, 4200-4E, 4200-5B, 4200-5E, 4240		
SENSOR CHARACTERISTICS	Refer to Table 1-2.		

TABLE 1-2. SENSOR CHARACTERISTICS

Sensor Type	Full-wave diode						Thermocouple type
Model	4200-4A	4200-4B	4200-4C	4200-4E	4200-5B	4200-5E	4240
Input	50Ω	50Ω	75Ω	50Ω	50Ω	50Ω	50Ω
Frequency Range	200kHz-7GHz	200kHz-12.4GHz	200kHz-1GHz	200kHz-18GHz	200kHz-12.4GHz	200kHz-18GHz	10MHz-18GHz
Power Range	1 nW to 10 mW fs				10 nW to 100 mW fs		1μW to 10 mW fs
Sum of Calibration Factor Uncertainty	1%, 0.2-300 MHz** 1.3%, 300 MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-7GHz	1%, 0.2-300MHz** 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz Add 0.05 dB/mW above 4 GHz			1%, 0.2-300MHz ** 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz Add 0.005 dB/mW above 4 GHz		1%, 10-300MHz** 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz
Max. SWR	1.12, 200kHz-2GHz 1.2, 2GHz-4GHz 1.4, 4GHz-7GHz	1.12, 200kHz-2GHz 1.2, 2GHz-4GHz 1.4, 4GHz-11GHz 1.6, 11GHz-12.4GHz	1.18, 200kHz-1GHz	1.3, 200kHz-4GHz 1.5, 4GHz-10GHz 1.7, 10GHz-18GHz	1.07, 200kHz-1GHz 1.10, 1GHz-2GHz 1.12, 2GHz-4GHz 1.18, 4GHz-12.4GHz	1.07, 200kHz-1GHz 1.10, 1GHz-2GHz 1.12, 2GHz-4GHz 1.18, 4GHz-12.4GHz 1.28, 12.4GHz-18GHz	1.5, 10 MHz-15MHz 1.35, 15MHz-10GHz 1.6, 10GHz-18GHz
Max. Average Power	10 mW (+10 dBm)				100 mW (+20 dBm)		10 mW (+10 dBm)
Overload Rating	300 mW (+25 dBm)				2W (+33 dBm)		30 mW (+14 dBm)*
RF Connector	Precision Type N male						
Calibration Factor	Individually calibrated at up to 9 frequencies, depending on sensor.						

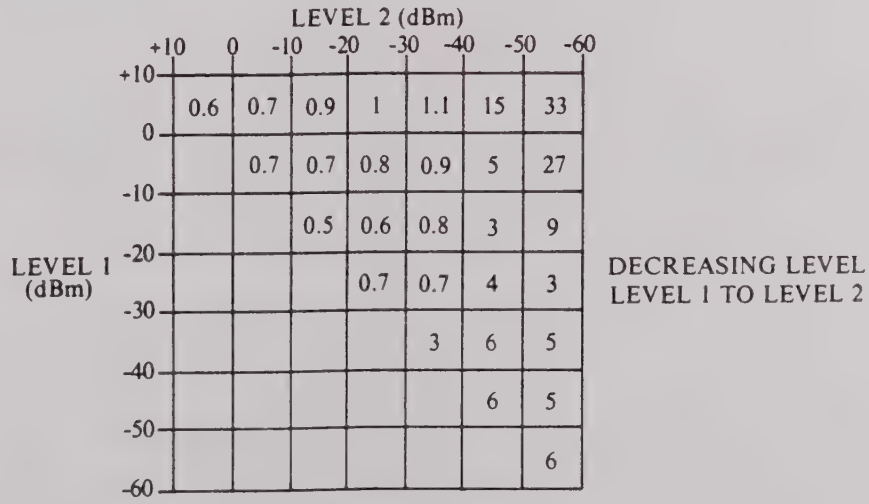
*While this sensor will withstand short periods of overload, extended overload operation may result in permanent change in characteristics, or even burnout.
**Calibration factor uncertainty is 0 at 50 MHz reference frequency

MAXIMUM RESPONSE TIME IN SECONDS
TO WITHIN SPECIFIED ACCURACY



LEVEL 1 (dBm)	+10	0	-10	-20	-30	-40	-50	-60
+10	0.5							
0	0.5	0.4						
-10	0.6	0.5	0.5					
-20	0.8	0.6	0.6	0.5				
-30	0.9	0.8	0.8	0.6	1.4			
-40	1.1	0.9	0.9	0.8	1.9	5.8		
-50	1.3	1.2	1.2	1.0	1.9	5.0	15.0	
-60								

MAXIMUM RESPONSE TIME IN SECONDS
TO WITHIN SPECIFIED ACCURACY



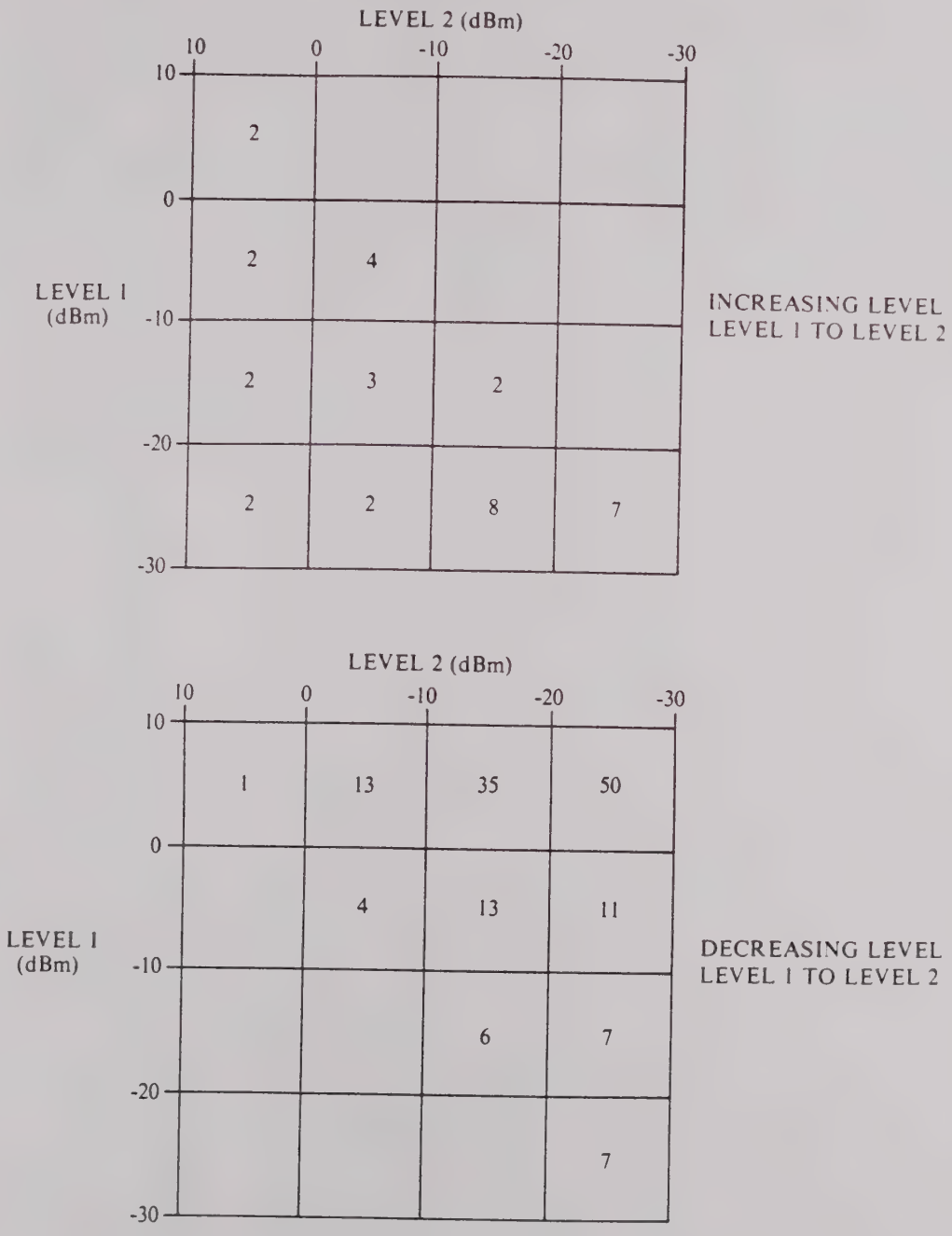
LEVEL 1 (dBm)	+10	0	-10	-20	-30	-40	-50	-60
+10	0.6	0.7	0.9	1	1.1	15	33	
0		0.7	0.7	0.8	0.9	5	27	
-10			0.5	0.6	0.8	3	9	
-20				0.7	0.7	4	3	
-30					3	6	5	
-40						6	5	
-50							6	
-60								

NOTE

Response times shown include interface time.

Figure 1-2 Maximum Response Time Chart for Series 4200-4 Sensors

MAXIMUM RESPONSE TIME IN SECONDS
TO WITHIN SPECIFIED ACCURACY



NOTE

Response times shown include interface time.

Figure 1-3 Maximum Response Time Chart for Instrument and 4240 Sensor

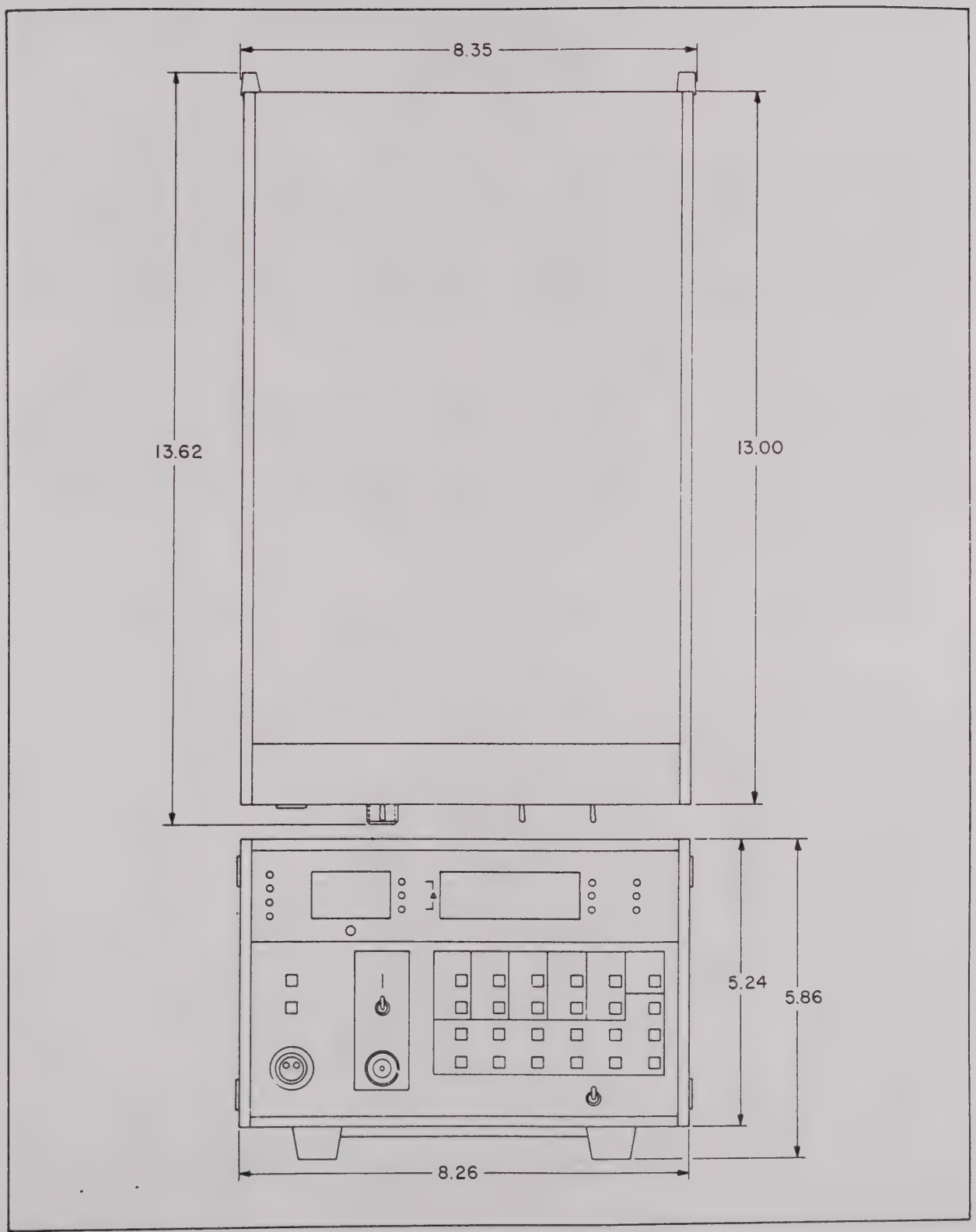


Figure 1-4 Outline Dimensions

SECTION II
OPERATION

2-1. GENERAL.

2-2. This section provides instructions for installation and operation of the instrument. Although the design of the instrument emphasizes ease of operation, it is recommended that the operator familiarize himself thoroughly with the material in this section before attempting to operate the instrument; otherwise, the full capabilities of the instrument may not be realized in use.

2-3. INSTALLATION.

2-4. Unpacking. The instrument is shipped complete with sensors (if ordered), and is ready for use upon receipt. Packaging details are shown in Figure 2-1. Unpack the instrument carefully, and inspect it for any signs of shipping damage. Should any damage be noted, notify the carrier and the factory immediately.

NOTE

Save the packing material and container for possible use in reshipment of the instrument.

2-5. Mounting. For bench use, choose a clean, sturdy, uncluttered surface. See Figure 1-4 for space requirements. For rack mounting, an accessory package, part number 950000, is available to mount one instrument, and another package, part number 950001, is available to mount two instruments side-by-side.

2-6. Power Requirements. The instrument has a tapped power transformer which permits operation from 100, 120, 220, or 240 volt ±10%, 50 to 400 Hz, single phase ac power sources. Power consumption is approximately 24 volt-amperes at 60 Hz.

2-7. Cable Connections. Interconnecting cable connections required depend upon the options installed and

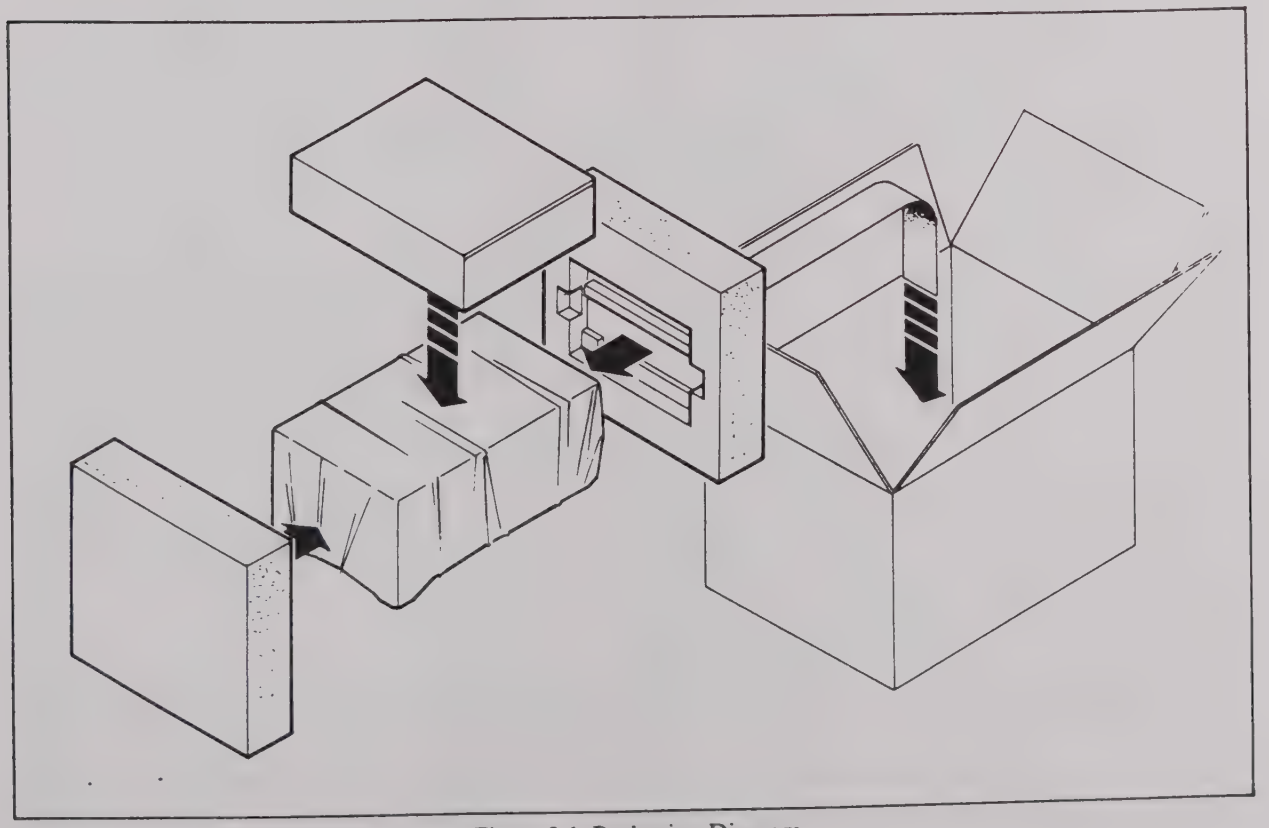


Figure 2-1 Packaging Diagram

the system applications of the instrument. A line cord and sensor cable are supplied with the instrument and an IEEE-488 interface cable is supplied with option -01; any other cables required must be supplied by the user. Cable connections that may be required are as follows:

a. **Sensors.** The sensor cable supplied with the basic instrument connects directly to the front-panel SENSOR connector, and the sensor that is to be used for power measurements connects directly to the other end of the sensor cable. Although the sensors are insulated against extreme temperature variations, it is advisable to locate the sensor away from heat sources when using the most sensitive ranges of the instrument. If the instrument is to be used to measure the output of equipment that generates heat significantly above the ambient temperature, a short length of coaxial cable or solid line having the same characteristic impedance as the sensor may be used between the sensor and the equipment undergoing test to allow heat to dissipate before reaching the sensor. If such a cable is used, the length must be kept as short as possible for operation at the high end of the frequency range; cable losses and an increase in SWR will tend to degrade measurement accuracy.

NOTE

The front-panel SENSOR connector is the input connector for channel 1 measurements. If the instrument is equipped with option -03, a sensor may be connected to the rear-panel connector marked SENSOR; the same conditions apply to this sensor connection. The rear-panel connector is the input connector for channel 2 measurements.

b. **Recorder Output.** Recorder connector J20 (type BNC) on the rear panel provides an analog dc voltage for application to a remote recorder. The output resistance is approximately 9000 ohms, delivering 1 milliampere into a 1000 ohm load for full scale input in the power mode. The analog dc voltage is proportional to the following:

1. In the power mode, it is proportional to displayed power, with 10 volts for full scale each range, either channel.

2. In the dB mode, it is proportional to displayed dBm with the relationship shown below:

dBm	Recorder Output
+20	10 volts
+10	9 volts
0	8 volts
-10	7 volts
-20	6 volts
-30	5 volts
-40	4 volts
-50	3 volts
-60	2 volts

3. In the channel 3 mode (option), it is similar to the dB mode, but for the channel 1 level only.

c. **Status Output.** Rear-panel connector P3 provides signal outputs for input disconnect during zeroing operations and high and low DB limit signals during dB measurements. The dB limits always test against the displayed value for operation. With the calibration factor and dB reference level equal to zero, the dB limits as entered prevail. With a dB reference level other than zero, the displayed value is checked against the limits chosen. In the channel 3 mode (option), the first limit exceeded, whether channel 1 or channel 2, activates the limit status. Pin connections are as follows:

Connector Pin	Signal
1	Common
2	Not used
3	Logic high indicates zeroing operation
4	Logic low within dB limits; logic high above high dB limit
5	Logic low within dB limits; logic high below low dB limit

2-8. OPERATING CONTROLS, INDICATORS, AND CONNECTORS.

2-9. Controls, indicators, and connectors used during operation of the instrument are shown in Figures 2-2 and 2-3. Table 2-1 lists their functions.

2-10. SENSOR CALIBRATION DATA.

2-11. Calibration corrections for sensors ordered with the instrument are written into microprocessor storage at the factory before shipment of the instrument and sensor. A copy of this information is stored under the right side cover. When the CAL FACTOR GHz function of the instrument is used during measurement, the microprocessor reads and interpolates the stored data on the basis of the specified measurement frequency, and corrects all measurement values accordingly. The microprocessor memory has storage capacity for calibration data for up to four sensors. Calibration corrections vary for different sensors; therefore, if sensors are to be substituted or added in the field, calibration data for these sensors must be written into memory in the field in order for the CAL FACTOR GHz function to be accurate. Note that it is not absolutely essential that calibration data be written into memory; the instrument can be used, although less conveniently, by reading calibration data off the chart on the sensor barrel and entering the proper dB correction through the front-panel keyboard using the CAL FACTOR dB function. For calibration data entry procedures, refer to paragraph 4-38; for the procedure for determining the calibration factor, refer to paragraph 4-39.

2-12. POWER APPLICATION.

2-13. The basic instrument is designed for operation

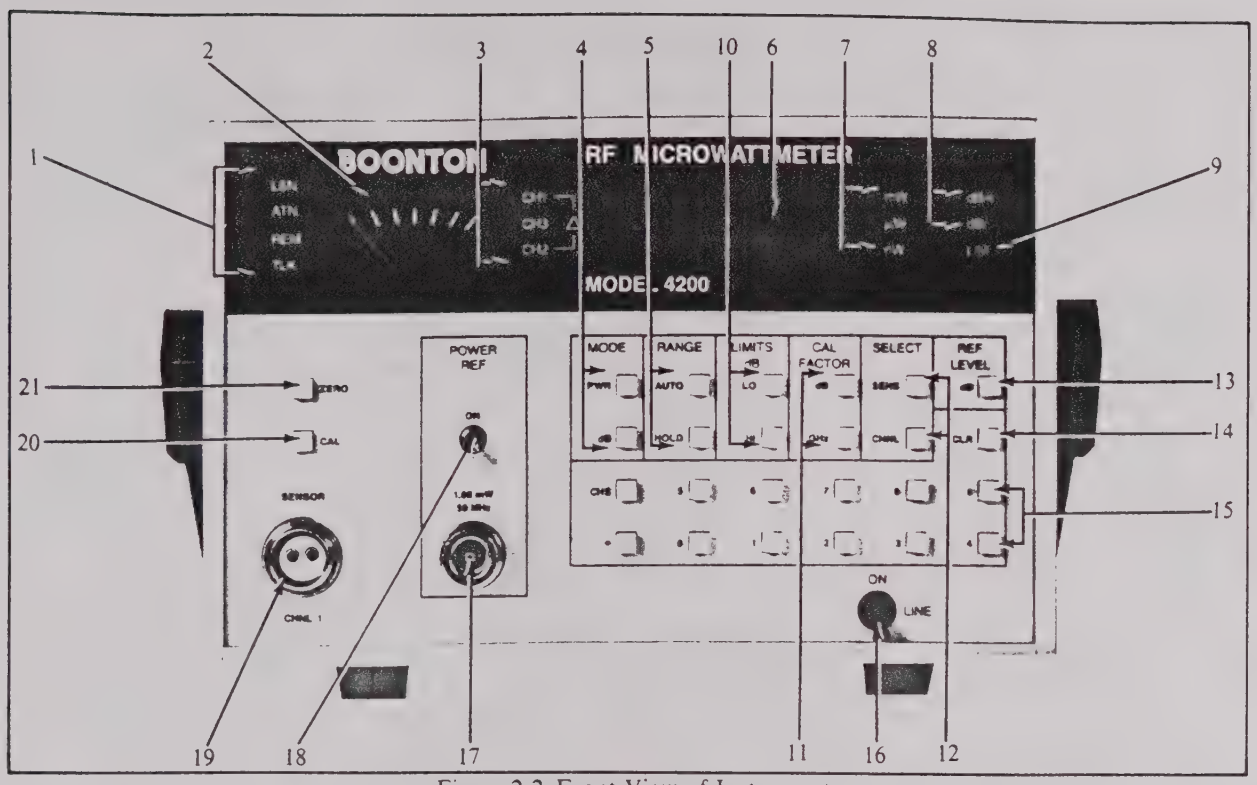


Figure 2-2 Front View of Instrument

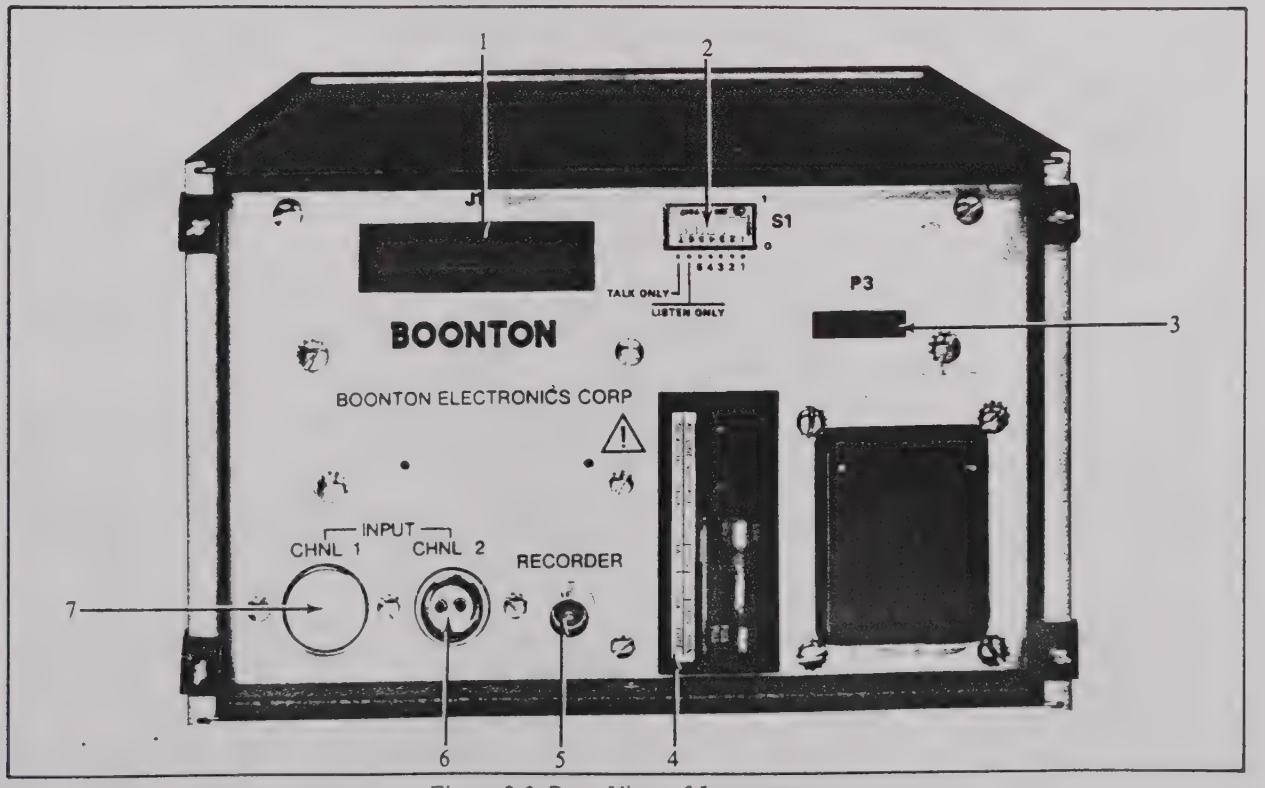


Figure 2-3 Rear View of Instrument

TABLE 2-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

Control, Indicator, or Connector	Figure and Index No.	Function	Control, Indicator, or Connector	Figure and Index No.	Function
LSN, ATN, REM, and TLK annunciators	2-2, 1	Provide indication of activity when IEEE 488 bus interface (option -01) is used.	SELECT keys	2-2, 12	Provide means for entering and recalling channel and sensor numbers.
Meter	2-2, 2	Provides relative indication of power and dB for peaking and nulling operations.	dB REF LEVEL dB key	2-2, 13	Provides means for entering and recalling a dB reference level.
			CLR key	2-2, 14	Provides means for clearing incorrect digit(s) entry; also provides means for clearing dB calibration factor and dB reference level to zero.
CH1, CH2, and CH3 annunciators	2-2, 3	Indicate channel in use.			
MODE keys	2-2, 4	Select LED display indication mode (POWER or dB).			
RANGE keys	2-2, 5	Select ranging mode (AUTO or HOLD).	Numerical, decimal point, and and CHS keys	2-2, 15	Provide means for entering signed numerical data.
LED display	2-2, 6	Four digit LED display with minus sign and decimal points; provides numerical indication of measured power or dBm, and of data entered or recalled through keyboard.	LINE switch	2-2, 16	Provides means for turning AC line power on and off.
			POWER REF connector	2-2, 17	Supplies 1 mW level at 50 MHz to 50 ohm load when POWER REF ON switch is set to ON position.
mW, μW, and nW annunciators	2-2, 7	Indicate units of power when instrument is operating in power mode.	POWER REF ON switch	2-2, 18	Provides means for turning internal power reference source on and off.
dBm and dBr annunciators	2-2, 8	Indicate dB mode in use when instrument is operating in dB mode.	SENSOR connector	2-2, 19	Provides means for connecting sensor to channel 1 input.
LIM annunciator	2-2, 9	Indicates when power level in dB is outside selected dB limits.	CAL key	2-2, 20	Provides means for calibrating instrument when sensor is connected to 1 mW source.
LIMITS dB keys	2-2, 10	Provide means for entering and recalling dB limits (LO and HI).			
			ZERO key	2-2, 21	Provides means for generating and storing zero corrections for all ranges with zero input to sensor.
CAL FACTOR keys	2-2, 11	Provide means for entering and recalling calibration factors in terms of dB or frequency.			

TABLE 2-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS (Cont.)

Control, Indicator, or Connector	Figure and Index No.	Function	Control, Indicator, or Connector	Figure and Index No.	Function
J1 connector	2-3, 1	Connector for IEEE 488 bus operation (option -01).	Power connector	2-3, 4	Provides connection for power cord, line voltage selection, and fusing.
S1 switch	2-3, 2	Provides means for selecting listen only function, talk only function, or instrument address when instrument is equipped with IEEE 488 bus interface option (option -01).	RECORDER connector	2-3, 5	Provides means for connecting analog DC voltage to remote recorder.
P3 connector	2-3, 3	Provides logic level signals for input disconnect during zeroing operations and high and low dB limit signals during dB measurements.	INPUT connector	2-3,6	Provides means for connecting sensor to channel 2 input (option 03).
			INPUT connector	2-3,7	Alternate position for INPUT channel 1 (option 04)

from a 100, 120, 220, or 240 volt, 50 to 400 Hz, single phase, ac power source. To apply ac power, proceed as follows:

a. Determine the line voltage at the ac power output receptacle.

b. Slide the plastic cover on the rear-panel power assembly so that the section that houses the fuse is uncovered. Look at the small printed circuit card located below the fuse, and note the voltage marking at the left corner of the printed circuit card. (The voltage marking is visible through the plastic cover.) If the voltage marking agrees with the voltage of the ac power source, the instrument is ready for power application. If the voltage marking does not agree with the voltage of the ac power source, remove the printed circuit card with small pliers and rotate and/or turn the printed circuit card so that the voltage marking in the left corner agrees with the voltage of the ac power source; insert the printed circuit card in this position.

c. Check the rating of the fuse in the rear-panel fuseholder. For 100 or 120 volt operation, the fuse should be a 0.3 ampere, MDL Slo-Blo type; for 220 or 240 volt operation, it should be a 0.2 ampere, MDL Slo-Blo type. If the rating of the fuse is incorrect, install a fuse of the required rating in the fuseholder. Slide the plastic cover back over the fuseholder.

WARNING

The instrument is designed to operate from a 3-terminal (one ground) ac power receptacle. If only a 2-terminal ac power receptable is available, use a 3-prong to 2-prong adapter. Connect the ground wire of the adapter to the power receptacle ground to eliminate a potential shock hazard to the operator.

d. Connect the power cord between the ac power connector on the rear panel of the instrument and the ac power receptacle (with adaptor, if necessary).

2-14. PRELIMINARY CHECK OF INSTRUMENT.

NOTE

The following checkout procedure is intended merely to demonstrate that the major circuits of the instrument are operating before the instrument is placed in service. For a detailed check of the instrument against performance specifications, refer to paragraph 2-37.

2-15. To perform a preliminary operational checkout, proceed as follows:

Set the LINE switch to the ON position.

b. Check operation of the LED display and the numerical keys by pressing the following keys in the sequence indicated and noting the LED display:

Press	Display
CLR	0000
.	0000.
0	000.0
1	00.01
2	0.012
3	.0123
CLR	0000
4	0004
5	0045
6	0456
7	4567
CLR	0000
8	0008
9	0089
CHS	-0089
CLR	0000

c. Enter measurement parameters by pressing the following keys:

1 SELECT CHNL
MODE dB
RANGE AUTO
0 CAL FACTOR dB
0 dB REF LEVEL dB
-90 dB LIMITS LO
90 dB LIMITS HI

d. Connect the sensor cable to the front-panel SENSOR connector, and connect the sensor to the free end of the sensor cable. Note the sensor number indicated on the barrel of the sensor, and enter this number through the numerical keyboard by pressing the numerical key corresponding to the sensor number and then pressing the SELECT SENS keys. (Example: 2 SELECT SENS.)

e. Check to see that the dBm and CH1 annunciators are lighted.

f. With zero input to the sensor, press the ZERO key. The instrument will be zeroed; the overall zeroing time is approximately 33 seconds. During the zeroing process, the instrument display will show the following in succession:

Display	Comment
cccc	Previous level clear time (approximately 15 seconds)
0000	Acquiring zero correction for range 0
0001	Acquiring zero correction for range 1
0002	Acquiring zero correction for range 2
0003	Acquiring zero correction for range 3
0004	Acquiring zero correction for range 4
0005	Acquiring zero correction for range 5
0006	Acquiring zero correction for range 6
cc03	Zeroing complete

g. Connect the sensor to the POWER REF connector. Set the POWER REF ON switch to the ON position. The LED display should indicate approximately 00.00 dBm (assuming that a 50-ohm sensor is used). If it does not, press the CAL key.

h. Key in .2 CAL FACTOR dB through the keyboard. The LED display should change to approximately 00.20 dBm.

i. Key in 0 CAL FACTOR dB through the keyboard. The LED display should return to approximately 00.00 dBm.

j. Key in 1 CHS dB REF LEVEL dB through the keyboard. The LED display should indicate approximately 01.00 dBr.

k. Key in 1 dB REF LEVEL dB through the keyboard. The LED display should indicate approximately -01.00 dBr.

l. Key in 5 LIMITS dB HI through the keyboard. The LIM annunciator should be off if a higher limit is in memory.

m. Key in 5 CHS LIMITS dB LO through the keyboard. The LIM annunciator should remain off if a lower limit is in memory.

n. Key in .5 CHS LIMITS dB HI through the keyboard. The LIM annunciator should remain off.

o. Key in .5 LIMITS dB LO through the keyboard. The LIM annunciator should light.

p. Key in 0 dB REF LEVEL dB through the keyboard. The LED display should indicate 00.00, the LIM annunciator should be off and the dBm annunciator should be lighted.

q. Press the MODE PWR key. The LED display should indicate approximately 1.000 mW.

r. Set the POWER REF ON switch to the OFF (down) position, and disconnect the sensor from the POWER REF connector.

2-16. OPERATING PROCEDURES.

2-17. Programming Measurement Parameters.

a. **General.** Measurement parameters are entered into the microprocessor through the front-panel keyboard. In order to eliminate the need for repeated reprogramming, parameters entered through the keyboard are stored in non-volatile memory, and the stored parameters are unaffected by instrument turn-off and turn-on. It is important to remember that the last used parameters are stored in the instrument because these stored parameters could cause what may appear to be erroneous indications when subsequent measurements are made. For example: if the instrument had been programmed for operation

with sensor 2 and sensor 1 is used instead, the LED display may be inaccurate if a GHZ calibration factor is entered because the sensor 2 calibration factors will be used by the microprocessor instead of the sensor 1 calibration factors. If there is any question about stored measurement values, the last entered values can be recalled for display as described in subparagraph b below. Measurement parameters may be changed at any time.

b. **Use of Numerical Keys.** The numerical keys are used to enter numerical values for LIMITS dB, CAL FACTOR, SELECT, and dB REF LEVEL functions. Whenever any numerical key is pressed, the microprocessor interrupts the measurement operation to accept new data. Numerical values are keyed in normal sequence, and keyed-in values enter the LED display from right to left. Up to four digits, plus decimal point and minus sign can be entered; entries exceeding four digits are ignored. Pressing the decimal point key places a decimal point after the right-most digit in the LED display. Pressing the CHS key changes the sign of the entry in the LED display; that is, plus becomes minus, or minus becomes plus. (The plus sign is not displayed.) If an error is made during entry of numerical values, press the CLR key and repeat the data entry process. When the LED display shows the desired numerical value, pressing the applicable LIMITS dB, CAL FACTOR, SELECT, or dB REF LEVEL key will cause the microprocessor to store the keyed in parameter and return automatically to the measurement cycle. Recall of the last entered values is accomplished by depressing the LIMITS dB HI, LIMITS dB LO, CAL FACTOR dB, CAL FACTOR GHz, SELECT CHNL, SELECT SENS, or dB REF LEVEL dB keys, as applicable. The value stored for the selected parameter is displayed on the LED display. When a recall is performed, the instrument remains in the recall state until either a MODE key or a RANGE key is depressed; the instrument then returns to the operating state.

c. **MODE Selection.** The MODE keys enable the operator to select the desired measurement mode. When the MODE PWR key is pressed, measured power levels are displayed in mW, μW, or nW; the annunciators associated with the LED display indicate the appropriate unit. When the MODE dB key is pressed, measurement values are displayed in terms of dB with respect to an operator-entered dB reference level. If 0 dB had been chosen as the reference level, the displayed numerical values represent dBm, and the dBm annunciator is lighted; selection of any other dB reference level causes lighting of the dBr annunciator, and displayed measurement values represent dB with respect to the selected reference level. Resolution of the instrument in the dB mode is 0.01 dB.

d. **RANGE Selection.** The RANGE keys enable the operator to select either automatic ranging or a range hold function. The automatic ranging function, which is most effective when measuring unknown or widely varying power levels, is activated by pressing the RANGE AUTO key, and the microprocessor then selects the appropriate measurement range automatically. If input power levels exceed the upper measurement limit of the instrument, an error indication (cc04) appears on the LED display; if input power levels are below the low measurement limit of the instrument, the instrument displays cc03. Ranging time is a function of a number of factors such as absolute level, change in level, analog response time, and direction of change. (See Figures 1-2 and 1-3.) The range hold function is useful when a series of measurements of approximately the same power level are to be made; selecting this mode eliminates delays due to ranging time. The range hold function is useful only in the PWR mode. When the RANGE HOLD key is pressed, the instrument remains on the measurement range that was active at the time the key was pressed. Input power levels that exceed the upper limit of this range cause an error indication (cc04) on the LED display; input power levels below the low limit of this range result in fewer significant digits in the LED display. If the minimum capability of the instrument is reached, the instrument displays cc03.

e. **LIMITS dB Selection.** The LIMITS dB keys enable the operator to program high and low dB limits into the instrument. Input power levels outside these limits will cause lighting of the LIM annunciator and activation of out-of-limit signals at rear-panel connector P3.

1. Limits are entered by keying in the numerical value in dB, using the numerical keys, and then pressing the LIMITS dB LO or LIMITS dB HI key, as applicable.

Example: To enter a low limit of -31.34 dB:

Press	Display
3	0003
1	0031
.	0031.
3	031.3
4	31.34
CHS	-31.34
LIMITS dB LO	

2. The dB limits always test against the value displayed. If the measurement is in dBm (0 dB REF LEVEL), the limit is in dBm. If any value other than 0 dB is chosen for the reference level, the limits operate in dBr (relative dB), which is the displayed value. If it is desired to have the limits operate on dBm when the REF LEVEL is other than 0 dBm, the value entered as the REF LEVEL should be subtracted algebraically from the desired dBm limits (reverse the sign of the dB REF LEVEL and add algebraically to the desired limit in dBm).

3. The dB limit function is always operative in the instrument. For all practical purposes, it can be cancelled, if desired, by entering a high limit of 90 dB and a low limit of -90 dB.

f. **CAL FACTOR Selection.** The sensors used with the instrument are frequency sensitive; that is, with a

constant input power level applied, their output signal level does not remain constant as the measurement frequency is changed. The CAL FACTOR keys provide means for introducing a calibration factor in terms of one of two parameters, either the actual dB calibration factor, or the measurement frequency.

1. A calibration chart is attached to the barrel of each sensor, and the calibration factor in dB for the measurement frequency being used can be computed from this chart. This dB calibration factor can then be entered into the instrument, using the numerical keys and the CAL FACTOR dB key, and the microprocessor will correct all subsequent measurements, both dB and power, automatically in accordance with the dB calibration factor entered.

Example: To enter a dB calibration factor of -0.3 dB:

Press	Display
.	0000.
3	000.3
CHS	-000.3
CAL FACTOR dB	

2. Reading and interpolation of the calibration chart can be tedious and subject to error or inaccuracy. The CAL FACTOR GHz function provides a simple, alternative method for calibration data selection. Calibration data for up to four sensors can be stored in the memory; such calibration data may be entered into storage at the factory or in the field. When the sensor number and the measurement frequency are entered through the keyboard, the microprocessor computes the required correction from the stored data and corrects subsequent dB and power measurements accordingly. The sensor number is entered using the SELECT function described in subparagraph g; the measurement frequency is entered using the numerical keys and the CAL FACTOR GHz key. To recall the last entered frequency for display, press the CAL FACTOR GHz key; to determine the calibration factor value for this frequency, press the CAL FACTOR dB key. Press a MODE key or a RANGE key to return the instrument to the operate mode.

Example: To specify a measurement frequency of 3.3 GHz:

Press	Display
3	0003
.	0003.
3	003.3
CAL FACTOR GHz	

g. **SELECT Function.** The SELECT keys are used by the operator to specify the number of the sensor to be used for measurements, and the measurement channel.

1. Calibration data for up to four sensors can be stored in the microprocessor. In order to use the proper calibration data when the CAL FACTOR GHz function is selected, the microprocessor must be advised as to which sensor is being used. The SELECT SENS key is used in conjunction with the numerical keys for this purpose. The sensor number is shown on the barrel of each sensor.

Example: To specify sensor number two:

Press	Display
2	0002
SELECT SENS	

2. The basic instrument contains only one measurement channel. This measurement channel is designated channel 1, and the front-panel SENSOR connector provides the input to this channel. An option is available for addition of a second measurement channel. When this option is included, the additional channel is designated channel 2, and input power levels are applied to this channel for measurement through a rear-panel connector. To further enhance the usability of the instrument, a channel 3 mode may be exercised. When channel 3 operation is specified, channel 1 and channel 2 levels are measured and compared by the microprocessor, and the difference in relative dB (with the channel 2 level as the reference) is displayed on the LED display. Channel 1 measurements, channel 2 measurements, or the channel 3 function can be selected using the numerical keys and the SELECT CHNL key.

Example: To select the channel 1 input for measurement:

Press	Display
1	0001
SELECT CHNL	

h. **dB REF LEVEL Selection.** The instrument normally uses 1 mW, 50 ohms as a reference for computing dBm measurement values; the dBm annunciator is lighted during such operation. The dB REF LEVEL dB key, used in conjunction with the numerical keys, enables the operator to select any other desired dB reference level; subsequent level indications are with respect to the selected reference, and this display mode is indicated by lighting of the dBr annunciator.

1. A dB reference level is entered by keying in the desired numerical value in dB, using the numerical keys, and then pressing the dB REF LEVEL dB key.

Example: To enter a dB reference level of -15.3 dB:

		Annunciators	
Press	**Display**	**dBm**	**dBr**
1	0001	Lighted	Off
5	0015	Lighted	Off
.	0015.	Lighted	Off
3	015.3	Lighted	Off
CHS	-015.3	Lighted	Off
dB REF LEVEL dB		Off	Lighted

2. To return to the dBm measurement display mode, enter a 0 dB reference level, or press the CLR and dB LEVEL dB keys.

Example:

		Annunicators:	
Press	**Display**	**dBm**	**dBr**
0	0000	Off	Lighted
dB REF LEVEL dB		Lighted	Off

NOTE

The maximum display capability of the LED display is ±99.99 dB. When operating in the dBr mode, keep this fact in mind. Avoid choice of dB reference levels that will result in display values that exceed the LED display capacity. Keyboard entries beyond the capability of the instrument produce error indications (cc01 or cc02 for entries too small or too large, respectively).

i. **Entry Limits.** Limits for entry of parameter values are as follows:

1. CAL FACTOR dB: -1.25 to +1.25
2. CAL FACTOR GHz: 0.1 GHz to 25 GHz, with minimum increment of 0.1 GHz
3. dB REF LEVEL: 0 to ±99.99, with minimum increment of 0.01 db
4. LIMITS dB LO and LIMITS dB HI: 0 to ±99.99, with minimum increment of 0.01 db.

j. **Recall of Entered Values.** The last entered value for each of the corresponding functions may be recalled for display on the LED display by pressing the following keys:

1. LIMITS dB LO
2. LIMITS dB HI
3. CAL FACTOR dB
4. CAL FACTOR GHz
5. SELECT SENS
6. SELECT CHNL
7. dB REF LEVEL dB

After any of the above keys are pressed, the instrument remains in the recall mode. To return to the operating mode, press any of the MODE keys or RANGE keys.

2-18. Zeroing the Instrument. For greatest accuracy, especially on the most sensitive ranges, the instrument must be zeroed. To eliminate the need for tedious and often inaccurate manual zeroing, the instrument incorporates an automatic zeroing capability. When automatic zeroing is initiated, the microprocessor reads, averages, and stores zero corrections for each measurement range of the instrument in approximately 33 seconds, and applies the proper zero correction for the range in use for all subsequent measurements. Zero corrections are most important on the most sensitive ranges of the instrument. During instrument warmup periods and use in environments with varying ambient temperatures, the instrument should be zeroed frequently if measurements are being made on the lowest ranges. To zero the instrument, proceed as follows:

CAUTION

Never press the ZERO key with a signal applied to the sensor; to do so will result in large, erroneous zero corrections and grossly inaccurate subsequent measurements.

a. Remove all input power to the sensor.

NOTE

If the instrument is subjected to strong noise fields, shield the sensor in accordance with the instructions in paragraph 2-35.

b. Press the ZERO key. The front-panel display will provide the indications listed in paragraph 2-15f while the microprocessor is computing and storing required zero corrections. When the ZERO key is pressed, a logic level signal is activated at rear-panel connector J3; this signal can be used to initiate turn-off of the device to which the instrument sensor is connected, if such operation is desired.

c. When the front-panel LED display shows cc03, zeroing has been completed and the instrument is ready for power level measurements.

2-19. Calibrating the Instrument. The instrument incorporates a power reference and automatic calibration facilities for fine sensitivity corrections. Sensitivity corrections are limited to a maximum of approximately ±3.5% from the original, factory set values as a precautionary measure. This feature protects against gross miscalibration which might occur if calibration were attempted with a power level other than that supplied by the power reference applied to the sensor. If computed calibration corrections from the factory set value exceed approximately ±3.5%, the instrument rejects the sensitivity correction and reverts to its previous sensitivity. To use the calibration function, proceed as follows:

a. Set the POWER REF ON switch to the ON position. Allow a stabilization period of approximately 30 seconds.

b. Program the instrument for power mode, autorange, and the appropriate measurement channel and sensor.

c. Enter a calibration factor of 0 dB through the keyboard.

d. Connect the sensor to the POWER REF connector.

e. Press the CAL key. The LED display should indicate 1.000 mW ±0.1% (±0.4% for 4200-5 sensors).

f. Set the POWER REF ON switch to the off (down) position, and disconnect the sensor from the POWER REF connector.

NOTE

If the instrument is supplied with a 75-ohm sensor (4200-4C), an adapter (P. N 950006) is also supplied. Use this adapter between the POWER REF connector and the sensor to convert the Type N POWER REF connector to a 75-ohm Type N. Before calibration, enter a 0.17 dB CAL FACTOR to compensate for the mismatch error that is introduced by the 75-ohm sensor.

2-20. Making Power Measurements. Once the instrument has been programmed, calibrated, and zeroed, it is ready for power level measurements. Merely connect the sensor to the source whose power level is to be measured. The power level will be displayed directly on the LED display.

2-21. Error Messages. Under certain conditions, the

LED display returns error messages as follows:

Display	Condition
cc01	Illegal entry, too low
cc02	Illegal entry, too high
cc03	Signal level out of range (low)
cc04	Signal level out of range (high)
cc07	Signal level out of range, one channel high, one channel low, in channel 3 mode of operation.

2-22. MAKING MEASUREMENTS.

2-23. Low-Level Measurements. The instrument will provide reliable, reproducible measurements of CW, AM, and FM power levels as low as 1 nW (-60 dBm). It can also be used for pulse measurements but with slightly decreased accuracy (±1 dB). Peak power levels for pulse measurements should not exceed 200 μW (20 μW for Series 4200-4 sensors); above this level the sensor enters the region where it operates out of the square-law region, and accuracy at such signal levels is correct for CW and FM only.

2-24. High-Level Measurements. Zeroing of the instrument is not critical when making high-level measurements (10 μW to 100 mW). CW and FM power measurements can be obtained within the specified accuracy up to 100 mW; accuracy cannot be guaranteed for pulse power measurements with instantaneous (35 μW for Series 4200-4 sensors) peaks exceeding 350 μW.

2-25. High-Frequency Measurements. At frequencies above 1 GHz, the appropriate sensor calibration factor must be entered through the keyboard if the specified accuracy of the instrument is to be realized. (Refer to paragraph 2-17f.)

NOTE

Model 4200-4A, 4200-4B, 4200-4E, 4200-5B, 4200-5E, and 4240 sensors are calibrated for use with a 50-ohm source; model 4200-4C sensors are calibrated for use with a 75-ohm source. Impedance mismatch results in increased SWR, which affects measurement accuracy. (Refer to paragraph 4-55 and Figure 4-12.) This effect can be reduced by inserting a low-SWR attenuator (SWR less than 1.10) or a low-loss tuner between the source and the sensor.

2-26. Temperature Effects. Specified instrument accuracies apply over an ambient temperature range of 21°C to 25°C. Operation outside this temperature range causes some additional error. Refer to table 1-1 for accuracy versus temperature. Figure 2-4 shows typical temperature characteristics of a Series 4200 sensor, and Figure 2-5 shows typical temperature characteristics of the instrument and sensor combined.

NOTE

For best zero stability of the instrument, allow the instrument and sensor to reach a stable temperature.

2-27. SWR Measurements. The high upper-frequency limit and sensitivity of the instrument facilitate SWR measurements with a slotted line. SWR measurements require only comparative, rather than absolute, measurement values; therefore, the instrument may be used up to 20 GHz with a model 4200-4E sensor. The front-panel meter is especially useful for rapid determination of maximum and minimum power points. SWR is determined by measuring the dB difference between a maximum and a minimum voltage point on a slotted line and converting this difference to SWR. An adapter, usually available from the slotted-line manufacturer, is required to couple the sensor to the slotted line. To make slotted-line SWR measurements, proceed as follows:

a. Connect the sensor to the sliding carriage, using a suitable adapter.

b. Ascertain that the signal source is turned off; then, zero the instrument.

c. Turn on the signal source and slide the carriage along the slotted line until a point of maximum indication is located. Adjust the source signal level and the probe setting for the least coupling that yields a -41 dBm reading at the maximum point. (The incident power should be at least 0 dBm.)

d. Slide the carriage along the slotted line until a minimum indication is located. Read the level at this point. Subtract the measured level at the minimum point from that at the maximum point, ignoring signs. Convert the resultant Δ dB into SWR, either through use of the SWR conversion chart (Figure 2-6) or by computation. SWR is the antilog, base 10, of Δ db/20.

2-28. Shielding Recommendations. If the instrument is subjected to strong noise fields, accurate zeroing may be difficult unless the sensor is shielded during the zeroing operation. The simplest method of shielding is to connect the sensor to the device whose power level is to be measured, first making sure that the device is turned off; however, is some instances, the device may act as an antenna and introduce additional noise voltage into the sensor. If this happens, disconnect the sensor from the device, stand the sensor, end down, on a copper plate, and hold it down firmly so that the rim of the sensor connector makes good contact with the copper plate at all points. Alternatively, wrap a piece of thin copper foil around the body of the connector body, and crimp the foil around the open end of the connector, making certain that the center pin of the connector is not shorted. If frequent zeroing in strong noise fields is necessary, construct an adapter, using a Type N connector permanently fitted with a copper foil shield.

2-29. Analog Output. A dc voltage proportional to either power or dBm is available at rear panel recorder connector J20 for recorder or other applications. This output voltage will be affected in both power and dB modes by calibration factor entries. The source resistance

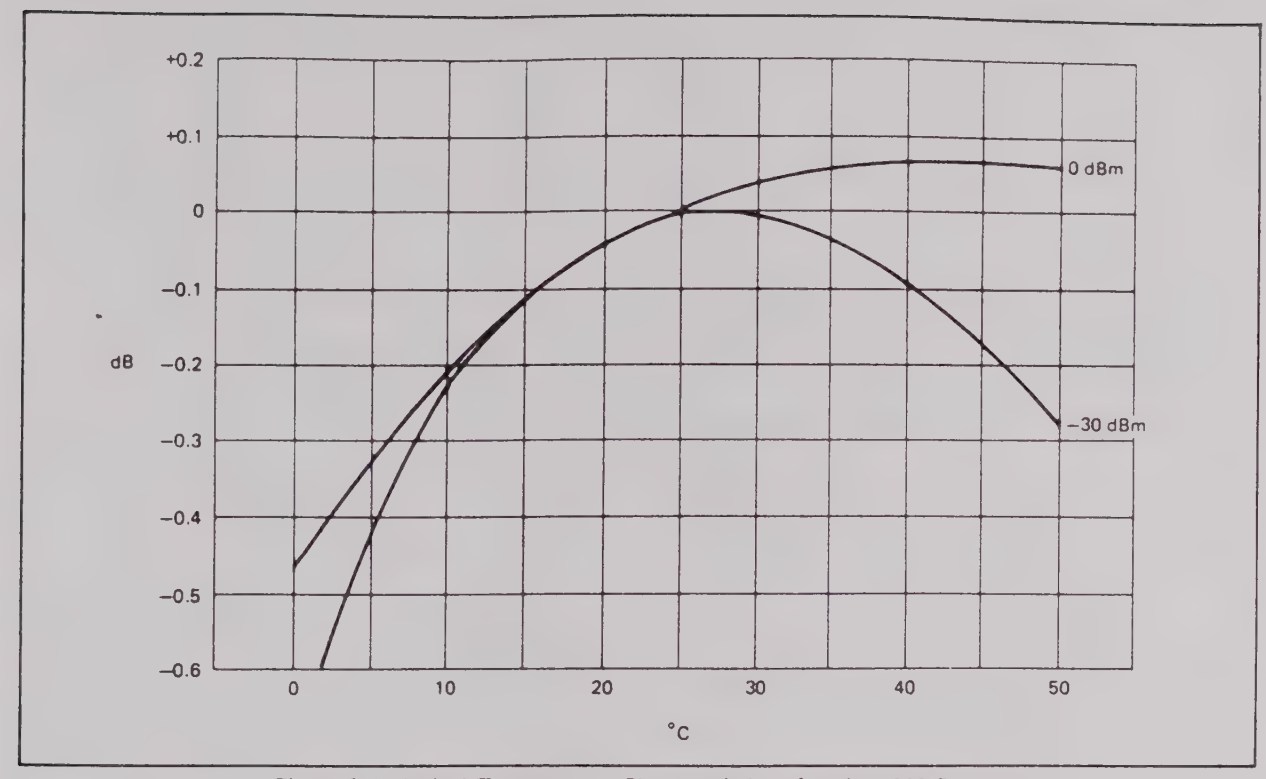


Figure 2-4 Typical Temperature Characteristics of Series 4200 Sensors

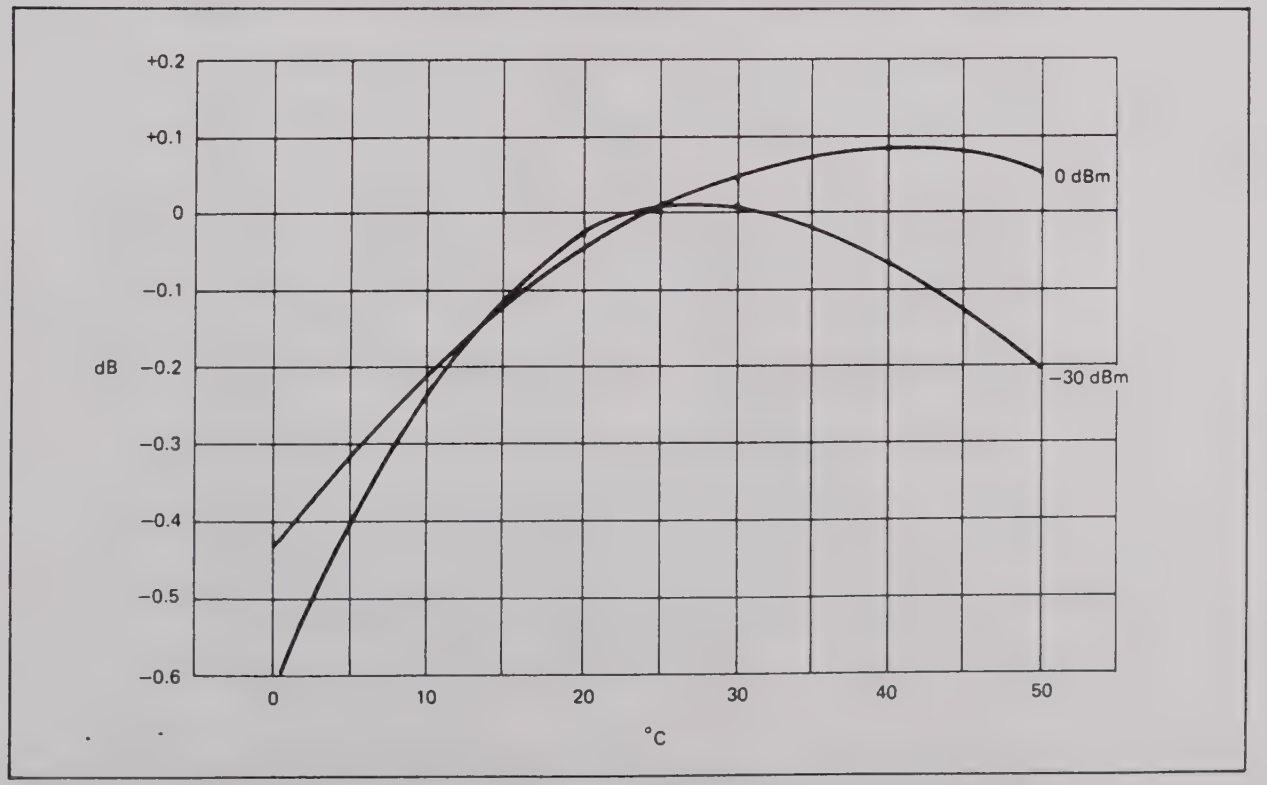


Figure 2-5 Typical Combined Temperature Charactistics of Instrument and Sensor

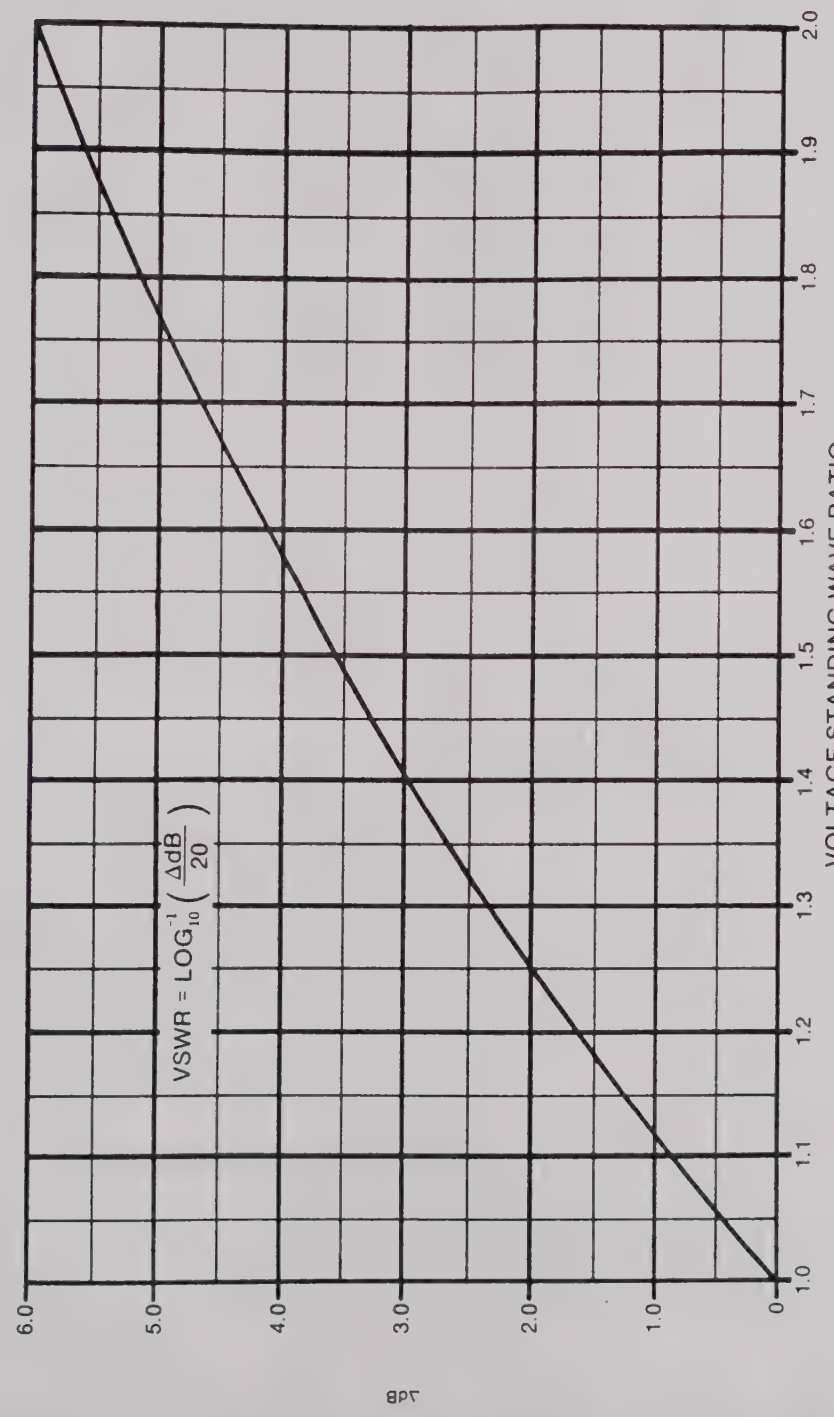


Figure 2-6 dB-SWR Conversion Chart

of the recorder output is approximately 9000 ohms, permitting a current of 1 mA into a load of 1000 ohms at full scale power. Output levels for various measurement modes are as follows:

1. In the power mode, the dc output level is proportional to the displayed power, with 10 volts at full scale for each range.

2. In the dB mode, the dc output level is proportional to dBm according to the formula:

$$V\ OUT = (8 + \frac{dBm}{10})\ volts$$

Example:

The voltage output at -20 dBm would be:

$$(8 + \frac{-20}{10})\ volts = 6\ volts$$

This output is a function of dBm only, and is unaffected by dB REF LEVELS entered.

3. In the channel 3 mode of operation (option), the recorder output is proportional to the dBm level of channel 1 only.

2-30. MINIMUM PERFORMANCE STANDARDS.

2-31. Test Equipment Required. For minimum performance testing of the instrument, an adjustable power source, such as the Boonton Electronics Corporation Model 25A Power Meter Calibrator, and a dc voltmeter or oscilloscope capable of measuring 0 to +10 volts are required.

2-32. Preliminary Setup.

a. Turn on the instrument and the adjustable power source and allow sufficient warmup time. If either unit had been stored at ambient temperatures substantially different from the ambient temperature at the minimum performance test facility, make sure enough time is allowed for each device to reach ambient temperature.

b. Set the adjustable power source output to zero, and connect the sensor between the adjustable power source and the front-panel SENSOR connector of the instrument, using the sensor cable.

c. Key in the following measurement parameter data through the keyboard:

1 SELECT CHNL
N SELECT SENS (N = number of sensor being used)
MODE dB
RANGE AUTO
LIMITS dB — any
0 CAL FACTOR dB
0 dB REF LEVEL dB

NOTE

Maintain the same measurement parameters for each of the following tests unless specifically directed otherwise.

2-33. Automatic Zero Function Test. To check the automatic zeroing function of the instrument, proceed as follows:

a. Ascertain that the signal input to the sensor is zero.

NOTE

Do not confuse 0 dB with zero input. For zero input to the sensor, turn off the adjustable power source.

b. Press the ZERO key and ascertain that the logic signal level at pin 3 of rear-panel connector P3 switches from a logic low to a logic high when the ZERO key is pressed, remains high throughout the zeroing period (approximately 33 seconds), and returns to a logic low at the end of the zeroing period. During zeroing, the front-panel LED display should show the following:

Display	Comment
cccc	Settling period
0000	Zeroing range 0
0001	Zeroing range 1
0002	Zeroing range 2
0003	Zeroing range 3
0004	Zeroing range 4
0005	Zeroing range 5
0006	Zeroing range 6
cc03	Zeroing complete

2-34. Autoranging Mode Test. To check the autoranging function of the instrument, set the output level of the adjustable power source to each of the values listed below and ascertain that the instrument LED display readout agrees with the input power level within ±0.2 dB:

+10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm

NOTE

For lowest ranges, rezero if necessary.

2-35. Range Hold Function Test. To check the range hold function of the instrument, proceed as follows:

a. Set the output level of the adjustable power source to 0 dBm.

b. Press the RANGE HOLD key and the MODE PWR key.

c. Ascertain that the LED display readout is 1.00 mW ±1.2%.

d. Set the adjustable power source output to each of the following levels in succession, and ascertain that the

corresponding listed LED indications are obtained on the instrument:

Power Source Level	Instrument Indication
10 mW	cc04 (power level too high)
1 mW	1.000 mW
100 μW	0.100 mW
10 μW	0.010 mW
	or
	cc03 (if less than 10 counts; power level too low)

e. Press the RANGE AUTO key.

NOTE

When the range hold function is selected, input power levels greater than the power decade operative when the selection was made will result in overranging of the instrument and display of an error indication; lower input levels result in a decrease in the number of significant digits in the display. Note that the decimal point and annunciator remain fixed.

2-36. Basic Instrument Accuracy Test. To check the basic accuracy of the instrument, proceed as follows:

a. With zero input to the sensor (adjustable power source turned off), zero the instrument by pressing the ZERO key.

b. Connect the sensor to the POWER REF connector. Set the POWER REF ON switch to ON. Press the CAL key.

c. Upon completion of calibration, press the MODE dB key, and connect the sensor to the adjustable power source.

d. Set the output level of the adjustable power source to each of the following dBm values in succession, and ascertain that the LED display readout agrees with the output level of the adjustable power source within the specified dB limits:

Power Source Level	LED Display Tolerance
-50 dBm	±0.1 dB
-40 dBm	±0.05 dB
-30 dBm	±0.05 dB
-20 dBm	±0.05 dB
-10 dBm	±0.05 dB
0 dBm	±0.05 dB
+10 dBm	±0.05 dB
-1 dBm	±0.055 dB
-2 dBm	± 0.06 dB
-3 dBm	±0.065 dB
-4 dBm	± 0.07 dB
-5 dBm	±0.075 dB
-6 dBm	±0.08 dB
-7 dBm	±0.085 dB
-8 dBm	±0.09 dB
-9 dBm	±0.095 dB

NOTE

If the dBm indications are within limits, it may be assumed that power mode indications are also within limits; dBm indications are computed from power measurements within the instrument.

2-37. Power Mode Check. To check operation of the instrument in the power measurement mode, proceed as follows:

a. Without disturbing any measurement parameters used in preceding paragraph 2-36, adjust the output level of the adjustable power source to 0 dBm and ascertain that the LED display of the instrument indicates 0 dBm ±0.05 dB.

b. Press the MODE PWR key. The LED display should indicate 1.00 mW ±1.3%.

c. If desired, other power levels may be checked in similar fashion. To determine the proper power indication for a specific dBm input level, use the formula:

$$P = \log^{-1} dB/10 \text{ (mW)}$$

2-38. Calibration Test. To check the automatic calibration capability of the instrument, proceed as follows:

a. Set the power source to 1.0 mW.

b. Select the power mode and autoranging.

c. Enter a 0 dB calibration factor.

d. Note the indication of the LED display. If the indication is not 1.000 mW, press the CAL key, and ascertain that the indication is now 1.000 mW ±2 counts (±4 counts with 4200-5 sensors).

e. If an indication of exactly 1.000 mW is obtained originally in step d, enter a calibration factor of 0.03 dB to cause the indication to increase to approximately 1.01 mW. Then, press the CAL key and ascertain that the indication changes to 1.000 mW ±2 counts. Enter a 0 dB calibration factor and press the CAL key to restore the original indication.

2-39. Sensor Selection Check. Entry of the correct number for the sensor in use is absolutely essential for instrument accuracy. Data for each sensor supplied with the instrument has been entered and stored in microprocessor memory at the factory. Stored data consists of functions peculiar to each sensor, such as sensitivity, calibration factors, etc. A direct, absolute check of the sensor data is not possible; however, the basic instrument accuracy test (paragraph 2-36) and the calibration test (paragraph 2-38) provide a good indication of satisfactory operation of the sensor selection function. Entry of an incorrect sensor number will probably result in degradation of basic accuracy. Sensor serial numbers can be recalled from non-volatile memory by keying in a decimal point followed by SELECT SENS.

2-40. dB Reference Level Function Test. To check the

dB reference level function of the instrument, proceed as follows:

a. Set the output power level of the adjustable power source to 0 dBm.

b. Press the MODE dB key and ascertain that the LED display indicates 0 dBm ±0.05 dB.

c. Enter a -10 dB reference level the pressing the following keys:

1
0
CHS
dB REF LEVEL dB

d. Ascertain that the LED display now indicates +10 dBr ±0.05 dB. The dBm annunciator should be off, and the dBr annunciator should be lighted.

e. Reset the instrument to indicate dBm by pressing the following keys:

0
dB REF LEVEL dB

f. Ascertain that the LED display again indicates 0 dBm ±0.05 dB. The dBm annunciator should be lighted, and the dBr annunciator should be off.

2-41. dB Limit Test. To check operation of the dB limit circuits, proceed as follows:

a. Set the output level of the adjustable power source to 0 dBm.

b. Enter a + 1 dB high limit by pressing the following keys:

1
LIMITS dB HI

c. Enter a -1 dB low limit by pressing the following keys:

1
CHS
LIMITS dB LO

d. Ascertain that the LIM annunciator is off.

e. Set the output level of the adjustable power source to -2.0 dBm. The LIM annunciator should light. The logic level at pin 5 of rear-panel connector P3 should be high; the logic level at pin 4 of connector P3 should be low.

f. Set the output level of the adjustable power source to +2.0 dBm. The LIM annunciator should be lighted. The logic level at pin 4 of rear-panel connector P3 should be high; the logic level at pin 5 of the connector P3 should be low.

NOTE

Limits can be entered only in terms of dB, not power; however, the limit function operates in both the dB mode and the PWR mode.

2-42. Calibration Factor Test. To check operation of the calibration factor function, proceed as follows:

a. Set the output level of the adjustable power source to 0 dBm.

b. Press the MODE dB key and note the indication on the LED display.

c. Enter a 0.7 dB calibration factor by pressing the following keys:

0
.
7
CAL FACTOR dB

d. Ascertain that the indication on the LED display is equal to the value noted in step b plus 0.7 dB.

e. Enter a 2 GHz calibration factor by pressing the following keys:

2
CAL FACTOR GHz

f. Determine the calibration correction for 2 GHz from the chart on the barrel of the sensor. Ascertain that the LED display indicates the value noted in step b plus the calibration factor read from the chart.

NOTE

For proper calibration factor correction and instrument accuracy, it is essential that the sensor number entered into the instrument prior to measurement agrees with the number indicated on the barrel of the sensor used for the measurement. Calibration factors that are invoked are operative in both the dB mode and the PWR mode.

NOTE

If the instrument is equipped with the -03 option, repeat the minimum performance standards tests for channel 2.

SECTION III
THEORY OF OPERATION

3-1. GENERAL.

3-2. The instrument is a general purpose RF microwattmeter capable of measuring power levels from 1 nW (-60 dBm) to 100 mW (+20 dBm). It is designed to operate in conjunction with Boonton Electronics Corporation Series 4200 power sensors. The usable frequency range depends upon the sensor used with the instrument. The lowest usable frequency for *calibrated* measurements is 0.2 MHz; the highest frequency is 18 GHz. Useful response for relative measurements can be obtained from 20 kHz to 20 GHz.

3-3. The instrument is a completely solid-state unit that employs a microprocessor for versatility in use. The microprocessor is controlled by a permanently stored, internal program; pertinent operating parameters can be entered by means of a front-panel keyboard. Use of a microprocessor enables automation of numerous functions, such as zeroing, calibration, sensor calibration, range selection, unit conversion, dB limit testing, relative dB measurements, etc. Measured values are displayed directly on a 4 digit LED display in terms of nW, μW, mW, dBm, or dBr (relative dB). Annunciators associated with the display indicate the unit of measurement. A meter is also provided for relative power measurements; this feature simplifies such operations as nulling and peaking.

3-4. OVERALL BLOCK DIAGRAM.
(See Figure 3-1.)

3-5. Sensor. Power levels to be measured are applied to an external sensor, which is connected to a front-panel connector through a five-foot sensor cable. Input power appears across a precision resistor (50 or 75 ohms, depending upon the sensor model). Because the resistance value is constant, the voltage developed across the resistor is a function of input power ($E^2 = PR$). The RF voltage developed across the resistor is converted to a DC voltage, and the resulting DC voltage is applied to the input module of the instrument.

3-6. Input Module. The input module receives the DC voltage developed by the sensor. Operating under control of the control module, the input module converts the DC signal to an AC signal, amplifies the AC signal, converts the amplified AC signal to an analog DC signal, and converts the analog DC signal to a digital signal. If the autoranging function of the instrument is being used, the gain of the amplifiers in the input module is adjusted automatically by the control module to accommodate any power level within the range of the instrument. The digital output signal of the input module is supplied to the control module for further processing; an analog DC output signal is developed from the digital signal and applied to the analog meter on the display module for relative power measurements, and to a rear-panel connector for application to a peripheral recorder.

3-7. Control Module. The control module consists primarily of a pre-programmed microprocessor. The microprocessor accepts and stores measurement parameter commands entered through the front-panel keyboard, and controls operation of the internal circuits of the instrument in accordance with its program and keyed-in commands. The microprocessor performs measurement value corrections based on stored zero corrections and stored or keyed-in sensor calibration factors, unit conversions based on selected measurement modes, and dB limit determination. The microprocessor also performs automatic instrument zeroing and calibration. The processed digital signal, which defines the final measurement value, is applied to a data bus and to the display module.

3-8. Display Module. The display module contains the keyboard and LED display circuits. Parameters to be used for power measurements can be entered at any time through the keyboard. Keyed-in values are read and stored by the microprocessor, and selected numerical values are shown on the LED display during parameter selection. Computed power levels are processed by the microprocessor in accordance with the keyed-in parameters; the digital values representing the final computed measurement values are decoded by the display module circuits to produce a direct LED readout of measured values and to activate the appropriate annunciators.

3-9. Power Reference. The power reference module generates a precision, 1.00 mW, 50 MHz signal that is used for calibration of the instrument. When this signal is applied to the sensor and the front-panel CAL key is pressed, fine sensitivity adjustments of the instrument are performed automatically under microprocessor control.

3-10. Power Supply Module. The power supply module provides all DC voltages required for operation of the internal circuits. It also provides a reset signal to the control module when it is powered up, and an interrupt signal if an undervoltage condition is detected. The

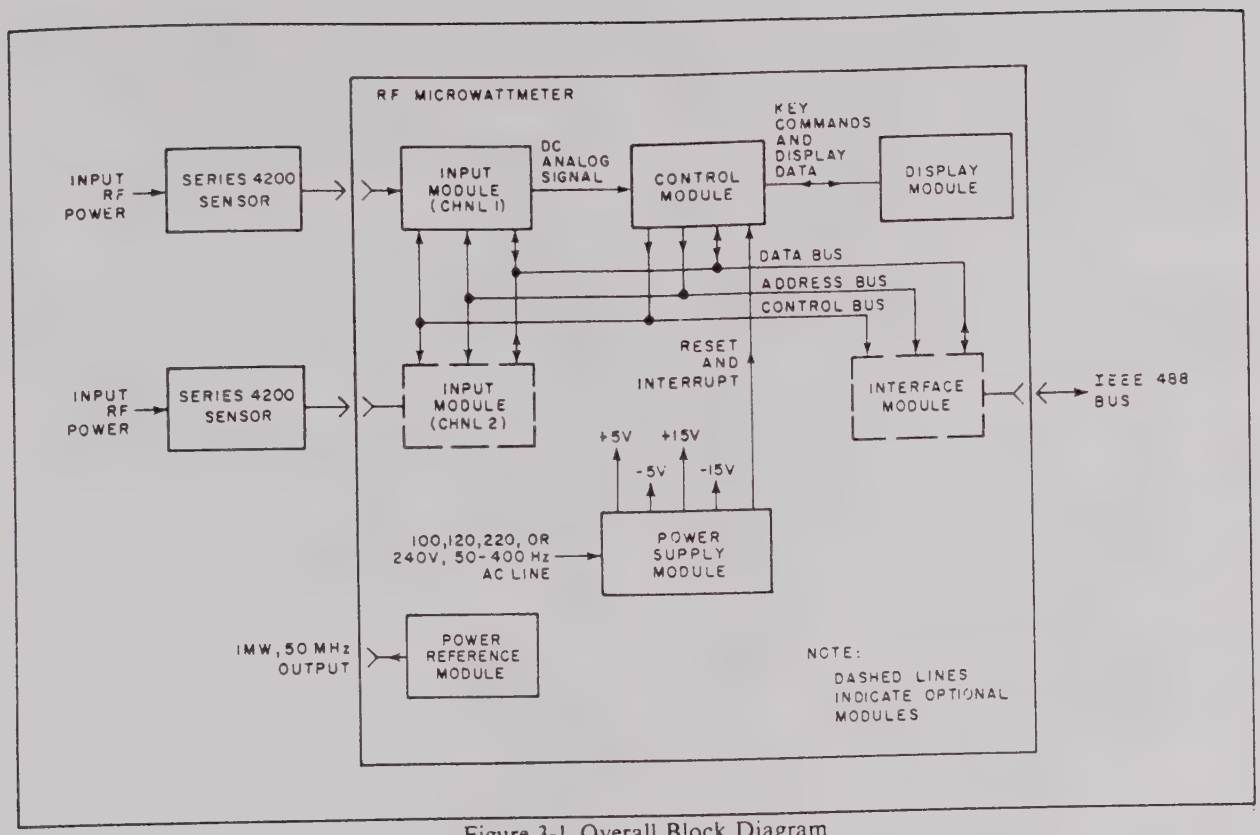


Figure 3-1 Overall Block Diagram

standard power supply module can be powered from a 100, 120, 220, or 240 volt, 50 to 400 Hz, AC power source.

3-11. Optional Modules. Standard options are available to further increase the versatility of the instrument. Two of these optional modules are shown in Figure 3-1.

a. A second input module can be added to the instrument to permit measurement of output power levels of two devices without the need for repeated switching of sensor connections. The input connector for this optional module is located on the rear panel of the instrument. The second input module also permits LED display of the difference between the power levels of the two devices, expressed in dB.

b. The interface module provides an IEEE 488 bus interface for remote control of instrument operation and for remote display of measured values.

3-12. DETAILED THEORY OF OPERATION, SENSOR CIRCUITS.

(See Figure 3-2.)

3-13. The sensor contains two paralleled precision resistors (50-ohm effective total resistance for Models 4200-4A, 4200-4B, 4200-4E, 4200-5B, and 4200-5E, and 75-ohm effective total resistance for Model 4200-4C) across which the input power is applied. With a constant load resistance, the RF voltage developed across the load resistance is a function of the RF power ($E^2 = PR$). The RF voltage is rectified by a full-wave rectifier that permits measurement of highly asymmetrical waveforms without substantial error. When the applied power level is within the square-law region of the diodes (up to approximately 20 μW), the sensor has a true RMS response. Above this power level, the sensor response approaches peak-to-peak, calibrated in the instrument in terms of true average power.

NOTE

Series 4200-5 sensors have a 10 dB input attenuator; this permits measurements to 100 mW (+20 dB). The most sensitive range is -40 dBm full scale, as opposed to -50 dBm for series 4200-4 sensors.

3-14. The body of the sensor has been designed and fabricated very carefully to eliminate any cavity resonance effects within the calibrated frequency range and to minimize noise. The sensor diodes are specially

selected for this application. The DC output voltage of the sensor is applied to the input connector of the instrument through a low-noise sensor cable.

3-15. DETAILED THEORY OF OPERATION, INPUT P.C. BOARD CIRCUITS.

(See Figure 3-3).

3-16. The input printed circuit board receives from the sensor a DC voltage that is a function of the power level being measured. Under control of the control board circuits, it provides amplification and signal processing required to develop an analog DC voltage and a digital signal that are proportional to the input RF power level. The input DC signal from the sensor is balanced in form and may vary from microvolts to volts, depending upon the input power level. The input printed circuit board must provide amplification with a wide range of gain, low offset voltage, and low noise; therefore, the input DC signal is converted to an AC signal which is amplified, and the amplified AC signal is converted to a DC analog signal and to a digital signal.

3-17. The input DC signal is converted to an AC signal by a chopper module, which plugs into the input printed circuit board. The chopper is composed of solid-state switches IC1a, IC1b, IC1c, and IC1d in a balanced arrangement, operating at a frequency of approximately 94 Hz to minimize AC line and line-related component interaction. The chopper drive signal is derived from the output of an astable multivibrator, which is completely independent of line frequency. The use of a solid-state chopper eliminates many of the problems, such as contact wear and contamination, associated with electromechanical choppers. The chopper supplies a balanced AC signal of approximately 94 Hz to the input amplifier.

3-18. The 94 Hz drive signal for the chopper is derived from the output signal of astable multivibrator IC5. Multivibrator IC5 drives flip-flops IC7a and IC7b, and these flip-flops supply the drive signal to the chopper circuits. Flip-flop IC7a also drives flip-flops IC8a and IC8b, which provide a 94 Hz, synchronized drive signal to the demodulator circuits that convert the amplified AC signal back to a DC signal.

3-19. Amplification of the balanced AC signal from the chopper is accomplished in an input amplifier composed of low-noise, operational amplifiers A5, A6, and A7. A balanced arrangement with degenerative feedback for stabilization and gain control is employed. The input AC signal is amplified by 1000, 100, 10, or 1, depending upon the instrument range. Demultiplexer IC6, under control of the control printed circuit board, adjusts the degenerative feedback in accordance with the range selected by the microprocessor to provide the required gain switching. An attenuator at the output of the input amplifier provides attenuation of 2 for the highest range only; on all other ranges its attenuation is zero. This attenuator is switched into the circuit on the highest range through solid-state switches IC10a, IC9b, and IC9c. Demultiplexer IC13 decodes digital signals that define the range from the microprocessor and activates the solid-state switches on the highest instrument range.

3-20. The amplified 94 Hz signal is converted to a DC analog signal by means of a demodulator circuit that operates in synchronism with the chopper. The demodulator consists essentially of a sample and hold switch, composed of solid-state switches IC10b and IC10c and associated circuitry. Switches IC10b and IC10c are controlled by the 94 Hz drive signals from flip-flops IC8a and IC8b. The sampling point and period of the sample

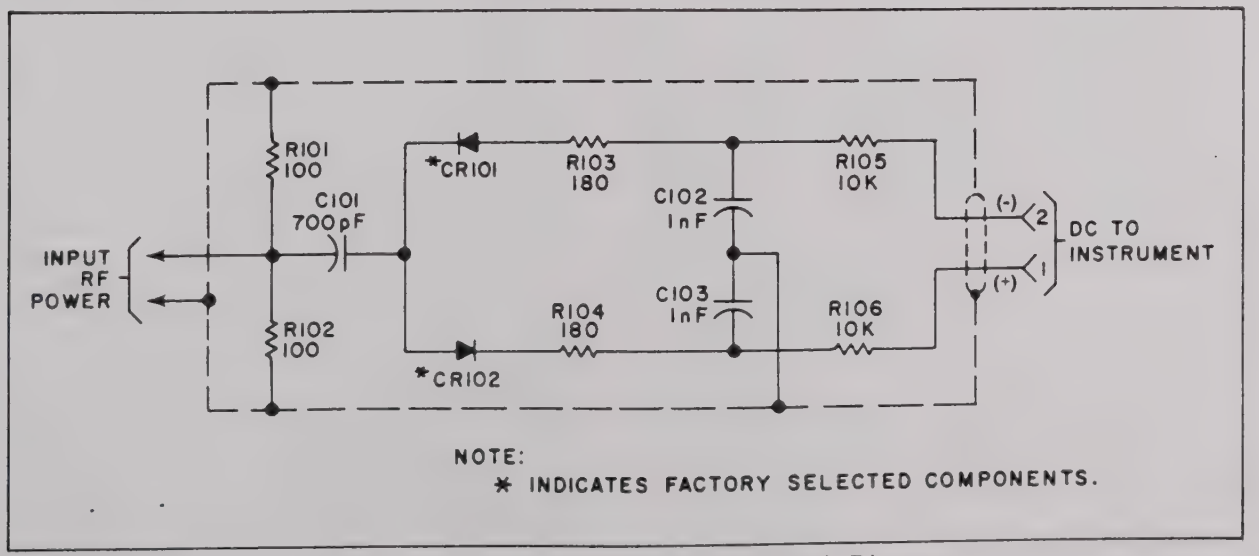


Figure 3-2 Typical Series 4200 Sensor, Schematic Diagram

and hold circuit has been chosen to minimize switching products and noise, and to vary signal averaging in accordance with the signal level. Switch IC9a adjusts operating parameters automatically in accordance with instrument range; the switch is activated through gates IC11b and IC11c and demultiplexer IC13 on the four highest ranges.

3-21. The DC output voltage of the sample and hold circuit is amplified by an amplifier circuit composed of integrated circuits A8, A9, and IC14, and associated circuitry. Integrated circuits IC14 is a demultiplexer which decodes microprocessor-supplied digital signals that define the selected range and adjusts an attenuator circuit accordingly; the gain of the amplifier is 125, 12.5, or 1.25, depending upon the selected range. The full-scale output voltage of the amplifier is 2.25 volts nominal on each range.

3-22. The DC output voltage of integrated circuit A9 is usually unipolar and positive; however, during the automatic zeroing process of the instrument, the DC output voltage may be positive or negative, depending upon small DC offsets. Because some of the following circuits operate only with unipolar signals, a polarity switch is required. This polarity switch, which consists of solid-state switches IC3b and IC3c, operates under control of the microprocessor on the control printed circuit board, which tests for polarity. The DC voltage is routed through the polarity switch to the appropriate input of operational amplifier A3 so that the output DC from this amplifier is always negative. This output voltage is applied to a comparator circuit.

3-23. Comparator A2 operates in conjunction with the microprocessor on the control printed circuit board and D/A converter IC2 to convert the DC output signal of amplifier A3, which is proportional to the input power, to a digital signal that can be processed by the microprocessor circuits. D/A converter IC2 is supplied with successive half-level digital signals (full scale/2, full scale/4, etc.) by the microprocessor. D/A converter IC2 converts these digital signals to a DC analog voltage, and this analog DC voltage is applied through amplifier A1 to comparator A2, where it is compared with the DC signal from amplifier A3. The difference signal from comparator A2 is supplied to the microprocessor through interface IC1 so that the microprocessor can monitor the results of the comparison and adjust the digital signal accordingly. The digital signal is adjusted by the microprocessor until the two input signals to comparator A2 are equal. The resulting digital signal then defines the input DC level being measured. This digital signal is then processed (zero correction, calibration correction, unit conversion, etc.) by the microprocessor before application to the LED display circuits of the instrument.

3-24. After the digital signal has been fully processed by the microprocessor, the processed digital signal is again supplied by the microprocessor to D/A converter IC2, which converts the processed digital signal to a corresponding DC analog voltage that is used to drive the front-panel meter and the recorder output of the instrument. This DC analog voltage from D/A converter IC2 is supplied through amplifier A1 to sample and hold switch IC3a, which is closed at this time by a control signal from the microprocessor. The DC analog voltage at the output of the sample and hold circuit is applied through amplifier A4 and the control printed circuit board to the display printed circuit board.

3-25. All interfacing between the input printed circuit board and the microprocessor is accomplished through interface IC1. Interface IC1 is an input/output device that operates under control of the microprocessor. When signal $\overline{RD}$ is activated by the microprocessor, data is transferred from the input printed circuit board to the microprocessor, provided that signal $\overline{CS}$ to interface IC1 is also active; when signals $\overline{WR}$ and $\overline{CS}$ are both activated by the microprocessor, data is transferred from the microprocessor to the input printed circuit board. Data flows between the input printed circuit board and the microprocessor over the eight-line bi-directional data bus. Routing of data through the interface is controlled by the address signals supplied to the interface by the microprocessor.

3-26. DETAILED THEORY OF OPERATION, CONTROL P.C. BOARD.

(See Figure 3-4.)

3-27. The operation of the instrument is controlled by a microprocessor contained on the control printed circuit board. The control printed circuit board is organized around a central processing unit (CPU), associated memories, input/output ports, and a 40-line bus. A stored program, in conjunction with key-entered commands, enables the microprocessor to perform a variety of functions, including the following:

a. Analog to digital conversion
b. Zero determination
c. Zero correction
d. Ranging
e. Calibration
f. Signal processing
g. Binary to BCD conversion
h. dB conversion
i. dB reference conversion
j. dB limit testing
k. Diagnostics.

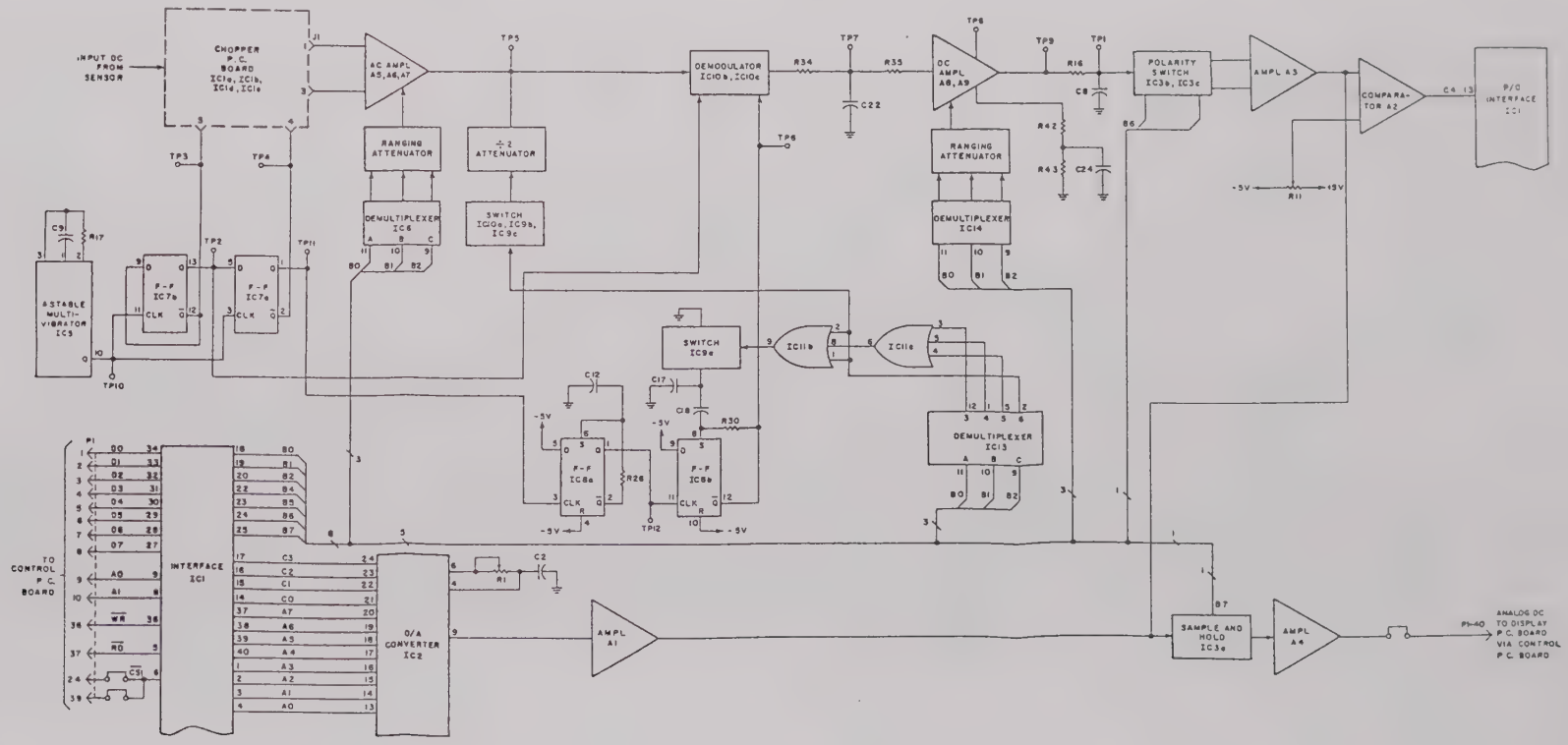


Figure 3-3 Input P.C. Board, Detailed Block Diagram

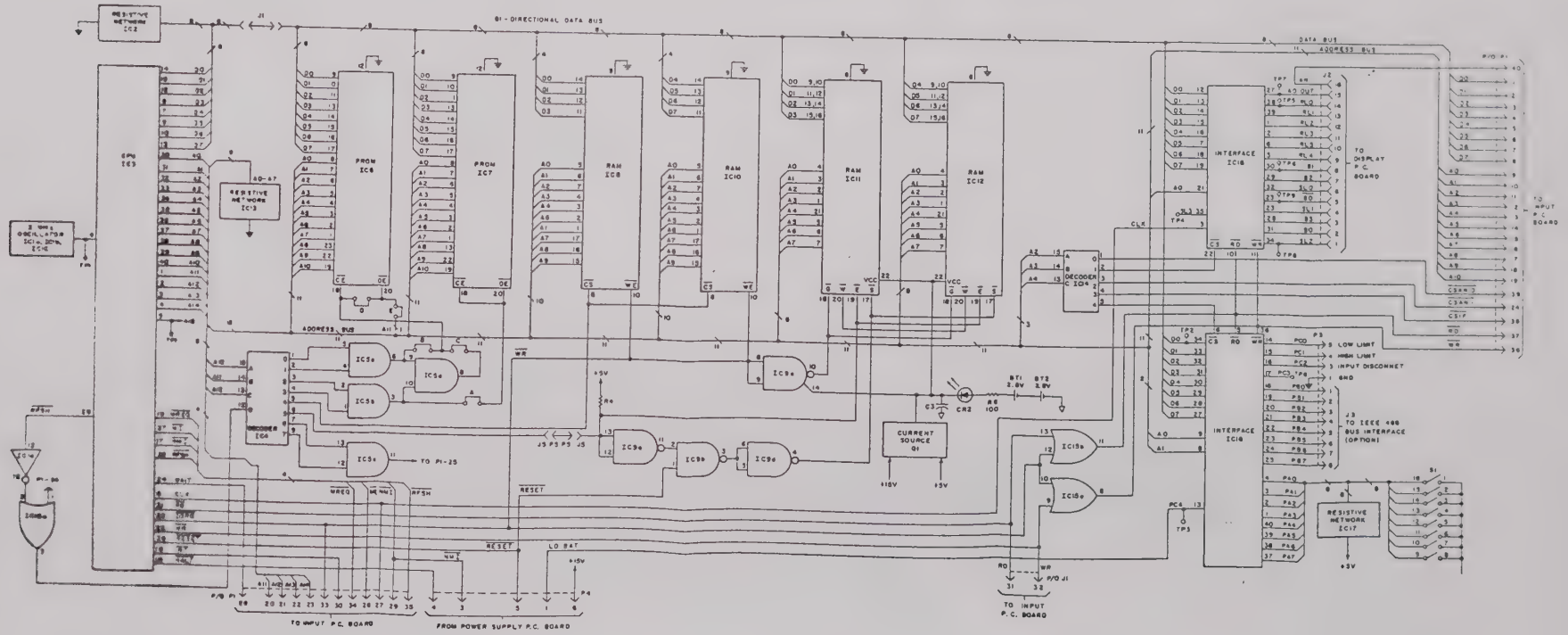


Figure 3-4 Control P C Board, Detailed Block Diagram

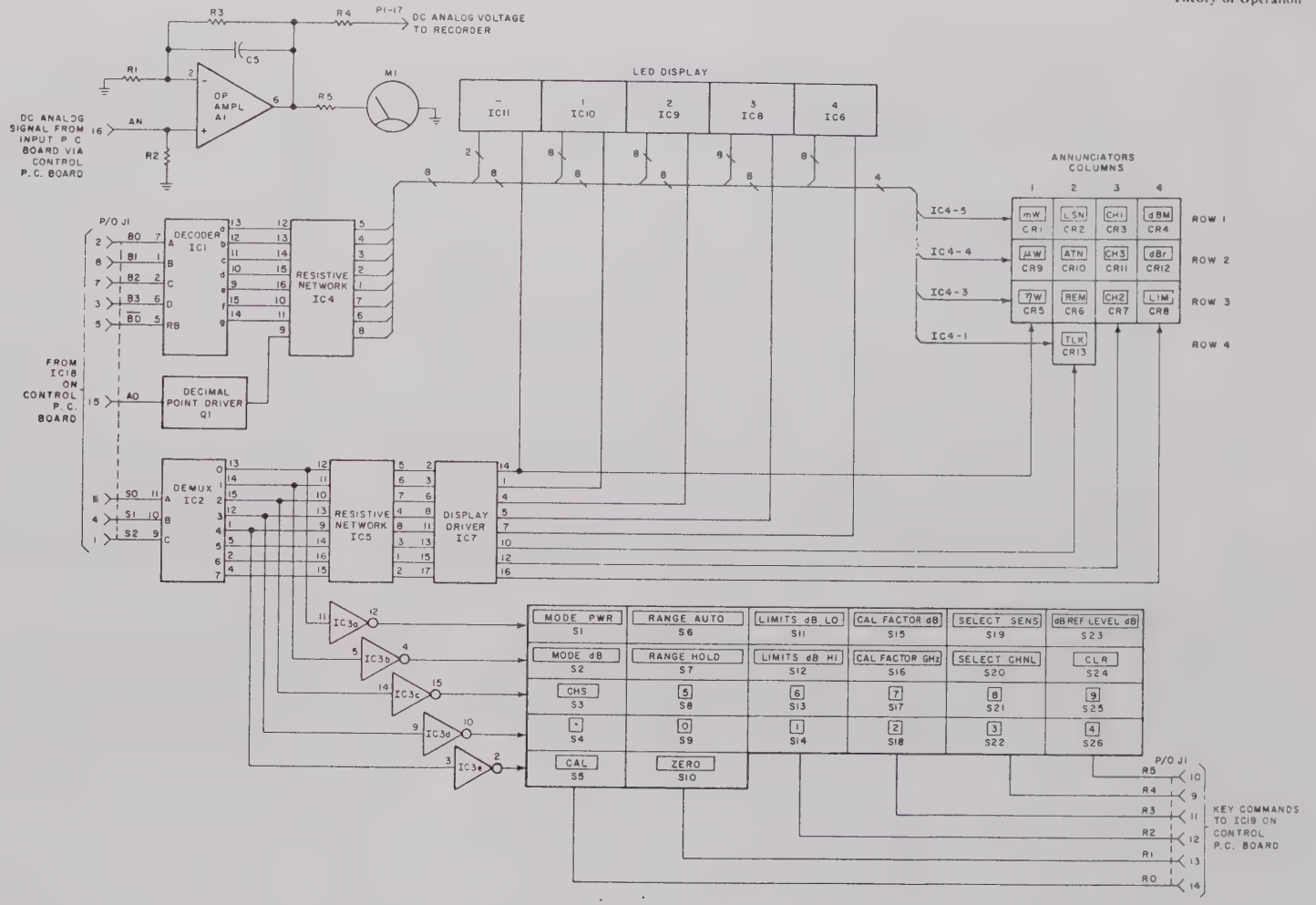


Figure 3-5 Display P.C. Board, Detailed Block Diagram

3-28. Integrated circuit IC3 is the microprocessor CPU. It is an 8-bit unit that operates at a clock frequency of 2 MHz, generated by integrated circuits IC1a through IC1c and associated circuitry. The operating program for the microprocessor is stored in integrated circuits IC6 and IC7, which are programmable read-only memories (PROMs). Integrated circuits IC8 and IC10 provide 1000 bytes of static RAM for use by the CPU for temporary storage of data during operation of the instrument. Integrated circuits IC11 and IC12 are used to store certain measurement parameters such as, sensor data, calibration factors, some key-entered parameters, etc. Lithium-type batteries BT1 and BT2, which have an anticipated life of 10 years, supply power to integrated circuits IC11 and IC12 during power-down of the instrument to enable retention of data stored in these memories; during normal operation, these memories are powered by transistor Q1. Integrated circuit IC16 is an I/O port which interfaces the following:

a. An 8-bit switch used to set the mode of operation, number of channels, and number of sensors.

b. A test socket (J3) used in signature analysis.

c. A plug (P3) for output of status information.

3-29. The CPU receives and transmits data over an eight-line data bus. A 15-line address bus is used for addressing, and a control bus is used for various control functions. When the instrument is turned off, signal $\overline{\text{RESET}}$ is activated by the power supply circuits and the microprocessor is reset to the start of the operating program; when the instrument is next turned on and DC voltages have reached the correct operating levels, the $\overline{\text{RESET}}$ signal is deactivated by the power supply circuits and the microprocessor begins to execute the stored program. Instructions are retrieved from storage by the CPU in accordance with the address code developed at its output. Decoder IC4 operates in conjunction with gates IC5a, IC5b, and IC5d to enable the appropriate PROM (IC6 or IC7), and the instruction contained in the memory location defined by the address on address lines A0 through A10 is read and transmitted by the CPU over the data bus. The CPU then executes this instruction.

3-30. During the measurement process, the CPU must retrieve data from storage and from the input and display printed circuit boards, it must store temporary calculation values, and it must output data to the input and display printed circuit boards. To retrieve data from memory, the storage device and data location are defined by the address supplied by the CPU. Integrated circuit IC4 decodes three of the address bits to develop an enabling signal for the appropriate memory IC. The other address bits define the location in storage of the data to be retrieved, and the data stored at this location is transmitted over the data bus to the CPU or to other circuits connected to the data bus. To access data developed by circuits outside the control printed circuit board, the CPU activates signals $\overline{\text{IORQ}}$ and $\overline{\text{RD}}$ along with the appropriate address lines. Decoder IC14 decodes three address bits to develop enabling signal CS for interface IC16, integrated circuit IC18, or interface IC1 on the input printed circuit board, as specified by the three address bits, and gate IC15b activates signal $\overline{\text{RD}}$ for the read function. If integrated circuit IC18 is enabled, keyed-in commands from the display printed circuit board, which had been stored in integrated circuit IC18, are transmitted over the data bus. If integrated circuit IC16 is enabled, input data from connector J4, bit switch S1, or power supply connector P4, as determined by address bits A0 and A1, is supplied through interface IC16 to the data bus. If interface IC1 on the input printed circuit board is enabled, data generated on the input printed circuit board is transmitted over the data bus through interface IC1.

3-31. To store data, the CPU activates signal $\overline{\text{WR}}$ and the address lines that define the storage device and storage location. Decoder IC4 decodes three bits of the address to enable the appropriate storage device, signal $\overline{\text{WR}}$ enables the write function of the selected device, and data on the data bus is written into memory at the location defined by the remaining address lines. To output data to circuits outside the control printed circuit board, signal $\overline{\text{IORQ}}$ is activated by the CPU in addition to the previously mentioned signals. Signals $\overline{\text{IORQ}}$ and $\overline{\text{WR}}$ activate the write enable signal to the device defined by the address bits. Decoder IC14 decodes three address bits to select the appropriate device (interface IC16, interface IC18, or interface IC1 on the input printed circuit board). Data on the data bus is then transferred to the selected device. If interface IC16 is selected, this data is transferred through interface IC16 to connector P3 or J3, as determined by address bits A0 and A1. The output to connector P3 consists of dB out-of-limit signals and an input disconnect signal which is active when the automatic zeroing function is selected. The output data at connector J3 is used in signature analysis checks. If interface IC18 is selected, the data on the data bus is written into storage in interface IC18 for application to the display printed circuit board. This data is then clocked out of storage to activate the LED display and annunciators on the display printed circuit board. If interface IC1 on the input printed circuit board is selected, data on the data bus is transferred through the interface to control various functions on the input printed circuit board.

3-32. Connector J1 is included in the data bus on the control printed circuit board to facilitate signature

analysis maintenance of the microprocessor circuits. When connector J1 is pulled out, the data bus is disconnected from the CPU, and the CPU executes successive NOPs for free-running signature analysis checks.

3-33. The CPU receives two control signals directly from the power supply printed circuit board. If the power supply voltage should drop during operation, or on equipment turn-off, signal $\overline{NMI}$ is activated by the power supply circuits; the CPU, upon receipt of this signal activates signal $\overline{HALT}$, and halts further execution of the program. Signal $\overline{HALT}$ is applied to the power supply printed circuit board, where it latches signal $\overline{RESET}$ to the active state. Signal $\overline{RESET}$, in turn, causes the microprocessor to return to the starting point of the program. When the power supply rises to a level approximately 150 millivolts below its nominal value, either as a result of correction of the undervoltage condition or of power turn-on, signal $\overline{RESET}$ is deactivated to permit execution of the stored program by the microprocessor.

3-34. DETAILED THEORY OF OPERATION, DISPLAY P.C. BOARD.

(See Figure 3-5.)

3-35. The display printed circuit board contains the instrument LED display, meter, annunciators, keyboard, and control circuits for these items. It interfaces directly with the control printed circuit board. When any keyboard key is pressed, the microprocessor on the control printed circuit board interrupts the normal measurement process and accepts and stores the key-entered commands; the microprocessor also supplies digital data to the display printed circuit board to cause keyed-in numerical values to appear on the LED display. The microprocessor resumes the normal measurement process when any of the terminator keys (LIMITS dB, CAL FACTOR, SELECT, dB REF LEVEL) is pressed. Upon completion of the measurement by the microprocessor, measurement values are supplied to the display printed circuit board.

3-36. Operation of the display printed circuit board is controlled by the microprocessor through integrated circuit IC18 on the control printed circuit board, which provides the following functions:

a. It provides a RAM for storage of microprocessor output data to the display printed circuit board.

b. It provides a first-in, first-out RAM which accepts and stores input information (up to 8 key commands) from the display printed circuit board.

c. It provides scan signals for both the LED display and the keyboard.

3-37. The LED display consists of four 7-segment displays, which provide a display capacity of four digits with decimal points, and a fifth display which is capable of displaying a minus sign. Each display consists of individual anodes for each segment that makes up the display and the decimal point, and a common cathode. The character that appears on the display is determined by the activated anodes at the time that the common cathode is scanned. The individual displays and the associated annunciators are scanned in sequence. The display duty cycle is 12.5%; that is, each digit or annunciator of the instrument is on 12.5% of the time.

3-38. Digital information for the LED display and annunciators is developed by the microprocessor, and is stored in the output RAM contained in integrated circuit IC18 on the control printed circuit board. Digital information that defines display and annunciator row selection is supplied to 8-channel demultiplexer IC2. The output lines of demultiplexer IC2 are activated in sequence, based on the input digital codes. The signal on the active output line of demultiplexer IC2 is applied through resistive network IC5 to display driver IC7, and the display driver supplies driving power for the corresponding display and the corresponding row of annunciators. At the same time, digital data that defines the display segments and the annunciators that are to be activated is supplied to decoder IC1. The binary-coded input is decoded by decode IC1, and the output lines of the decoder are activated in accordance with this decode. The outputs of the decoder activate the individual anodes of the selected display and the individual annunciators in the active annunciator row, thereby providing the appropriate instrument display. A decimal point signal is applied through transistor Q1, when appropriate, to cause a decimal point to be displayed to the right of the character on the active display.

3-39. Demultiplexer IC2 also provides scanning signals to the keyboard. As each of its first five output lines is activated in sequence, a scan signal is applied to an individual row or the keyboard through an inverter. If any key in the row being scanned is pressed, a signal is supplied to one of the column output lines to the RAM in integrated circuit IC19 on the control printed circuit board, and the key command is stored by the RAM. Key selection is defined by a combination of the row scan signal and the column output line. The RAM can store up to a maximum of eight key commands, and it delivers this stored information to the microprocessor when it is read. Actuation of more than eight key commands without a read causes the RAM to be cleared.

3-40. Analog DC voltage, which is proportional to the measured power level, is supplied from the control

printed circuit board to amplifier A1. The output signal of amplifier A1 drives the front panel meter to provide a relative indication of measured power for peaking and nulling applications. The amplifier also supplies a DC analog voltage to rear-panel connector P1. This signal can be used to drive an external recorder.

3-41. DETAILED THEORY OF OPERATION, POWER REFERENCE P.C. BOARD.

(See Figure 3-6.)

3-42. The circuits on the calibrator printed circuit board are used to develop a 1 mW reference power level with a 50-ohm source resistance. This reference level can be used for automatic calibration of the instrument. Operation of the calibrator circuits is controlled by the front-panel POWER REF ON switch.

3-43. The reference signal is generated by transistor oscillator Q1, which operates at a frequency of approximately 50 MHz. An automatic leveling circuit is used to maintain a constant reference power level. Leveling is achieved by rectifying the oscillator output signal in the signal level detector circuit, and comparing the resulting DC voltage with a stable DC voltage developed by voltage reference IC1. The difference voltage is amplified by operational amplifier A1, and the output level from the operational amplifier controls a varactor in a capacitive divider that determines the drive to the oscillator. The output of the operational amplifier adjusts the varactor effective capacitance as required to adjust the drive to the oscillator in the direction and amount required to maintain a constant output level. A second capacitive divider at the output of the oscillator divides the oscillator output signal and tends to provide some isolation from the load. Because the source impedance of this divider is low, a 50-ohm series resistor is used to establish the desired 50-ohm source resistance. The output reference power level signal is available at the front-panel POWER REF connector.

3-44. DETAILED THEORY OF OPERATION POWER SUPPLY P.C. BOARD.

(See Figure 3-7)

NOTE

The following paragraphs refer to instruments having serial numbers of 531 and up. For instruments with lower serial numbers, see Appendix.

3-45. The power supply printed circuit board performs the following functions:

a. Converts 100, 120, 220, or 240 volt 50 to 400 Hz, ac line power to -5, +5, +5.2, +15, and -15 volts dc for system operation.

b. Generates a power-up signal for the microprocessor when supply voltages reach the proper values for system operation.

c. Activates an interrupt signal to the microprocessor when supply voltages drop to levels too low for reliable operation.

3-46. Input ac line power is supplied to the primary of power transformer T1 on the main chassis through fuse F1, line switch S1, and a line voltage selector printed circuit card.

3-47. Power transformer T1 steps down the ac line voltage to two secondary windings. These voltages are rectified by bridge rectifiers CR1 and CR2. The dc voltage supplied by CR1 is filtered by C1 and C2 and drives regulators IC2 and IC3 which develop +15 and -15 volts, respectively. The regulated -15 volt supply also drives regulator IC5 to develop the -5 volt supply.

3-48. The dc voltage developed from CR2 is filtered by C3 and drives regulator IC4 to produce +5.2 volts. R5 provides adjustment for the +5.2 volt supply.

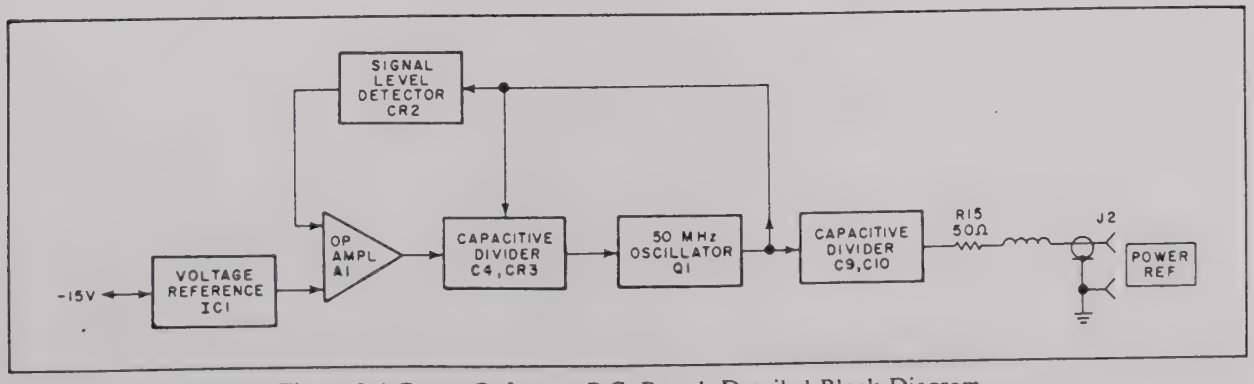


Figure 3-6 Power Reference P.C. Board, Detailed Block Diagram

3-49. The unregulated +15 volt supply also drives regulator IC1 to produce +5 volts to power A1, IC6, and generate a voltage reference at the junction of R7 and R8.

3-50. The output voltage of the +5.2-volt regulated DC supply is monitored by comparator A1a to develop a power-up signal on turn-on and an interrupt signal under undervoltage or power-down conditions. When the instrument is turned on, comparator A1a develops a positive output pulse when the output of the +5.2-volt regulated supply rises to a value approximately 150 mV below the nominal output voltage; the exact power-up signal point is adjustable by means of potentiometer R11. The positive output pulse of comparator A1a clocks flip-flop IC6 to deactivate signal $\overline{\text{RESET}}$ to the microprocessor on the control printed circuit board. If the output voltage of the +5.2-volt regulated supply should drop below the reliable usable level during operation of the instrument and during instrument shut-down comparator A1a switches its output level to a logic low, thereby activating signal $\overline{\text{NMI}}$ to the microprocessor. The microprocessor activates signal $\overline{\text{HALT}}$, which resets flip-flop IC6, thereby latching signal $\overline{\text{RESET}}$ low to ensure resetting of the microprocessor to the start of the program.

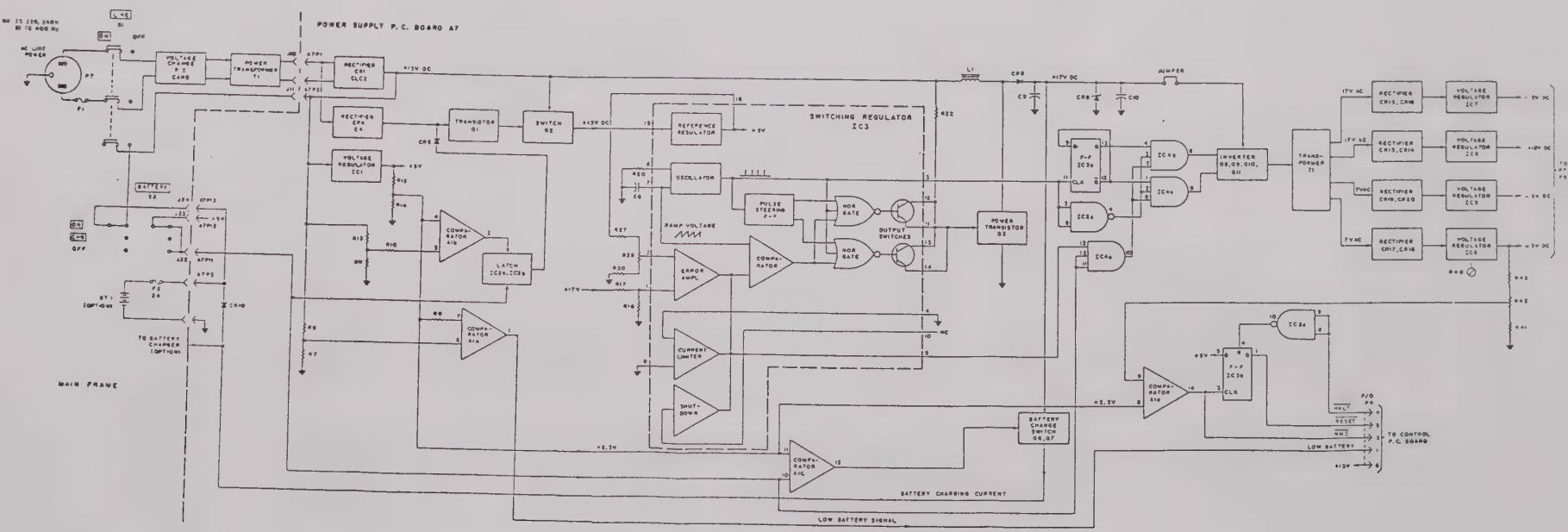


Figure 3-7 Power Supply P.C. Board, Detailed Block Diagram

SECTION IV
MAINTENANCE

4-1. GENERAL.

4-2. This section contains maintenance instructions for the instrument. Included are a list of required test equipment, trouble localization procedures, instrument adjustment and sensor calibration procedures. Minimum performance checks are included in Section II; these checks should be performed whenever there is any doubt about instrument performance.

4-3. TEST EQUIPMENT REQUIRED.

4-4. Table 4-1 lists test equipment required for maintenance of the instrument. Test equipment of equal capability may be substituted for any listed item except the model 5004A signature analyzer (unless it is known that the substitute signature analyzer agrees completely with the model 5004A) and the model 2500 range calibrator.

4-5. TROUBLESHOOTING CONCEPT.

4-6. The instrument employs both analog and digital circuitry. The digital portion uses a microprocessor in a bus-oriented system. DC and AC measuring instrument such as voltmeters and oscilloscopes have been the traditional test instruments for electronic instrument maintenance; however, in a microprocessor-based bus-oriented system, such test equipment, while still useful and necessary, leaves much to be desired. With such test equipment alone, troubleshooting in a bus-oriented system is extremely tedious and time-consuming, if not impossible. A new technique called signature analysis has been devised to deal with microprocessor-based systems, and the troubleshooting procedures in this manual are based on signature analysis techniques.

4-7. SIGNATURE ANALYSIS.

4-8. A complete discussion of signature analysis is beyond the scope of this manual; however, a brief discussion will aid in maintenance of the instrument. Long, complex data streams are present in microprocessor bus-oriented systems. In signature analysis, with the system operating at normal speed, these data streams are compressed into concise, easy to interpret readouts (signatures) measured at pertinent nodes. By choosing or generating appropriate measuring periods or windows, these signatures become unique; one and only one signature occurs at each node if operation is normal. Using signature analysis, it is possible to proceed through the instrument in an orderly fashion until a faulty signature is obtained. Generally, at this point, it is possible to identify one component as the most probable cause of the malfunction. In this instrument, all integrated circuits and transistors are socket-mounted to make removal and replacement without unsoldering possible.

TABLE 4-1. TEST EQUIPMENT LIST

Nomenclature	Model No.
Digital Multimeter	Data Precision 1450
Oscilloscope	Hewlett-Packard 1740A
Power Meter Calibrator	Boonton Electronics 25A
Signature Analyzer	Hewlett-Packard 5004A
Diagnostic ROM	Boonton Electronics P/N 950004
Range Calibrator	Boonton Electronics 2500
Milliwatt Test Set	W & G EPM-1
NOTE: The following items are required only for determination of calibration factor and effective efficiency.	
Standard Power Meter	Any Power Meter
Signal Generator	Any model that covers frequencies of interest.
Double-stub Tuner	Any model with stub spacing and travel suitable for measurement frequencies.
Directional Coupler 50-ohm Precision Termination 6 dB, 50-ohm Attenuators (2) 50-ohm Termination R-F Microwattmeters (2)	Boonton Electronics 4200 (calibrated)

4-9. Signature analysis checks are of two basic types: "free-running" and "stimulated" or programmed. In free-running checks, the data bus between the microprocessor and the system is opened, and an instruction that will cause the microprocessor to free-run is forced. The microprocessor then runs through its address field

repeatedly. Free-running checks may be used to check the following:

a. Microprocessor address output
b. Memory select decoding
c. I/O select decoding
d. ROM program

4-10. In the stimulated mode, the data bus between the microprocessor and system bus is left intact, and programs provided in a special ROM are invoked to conduct the desired tests. In this instrument, the stimulated mode is used to check the following:

a. RAM operation
b. Display functions and scanning
c. Keyboard
d. I/O ports

4-11. In this instrument, programmed signature analysis tests are activated by setting a bit switch, located at the rear of the control board, to the number associated with the particular test. In using signature analysis, the free-running tests should be performed first to ascertain that the microprocessor is putting out a normal address field, that the memory and I/O decoding is correct, and that the ROM contents are normal.

4-12. The signature analysis technique is applicable only to the digital section of the instrument. Some sections of the instrument employ both analog and digital circuits. The input module, for example, receives a DC analog signal and amplifies the analog signal before converting it to a digital signal. The power supply uses both digital and analog circuitry to develop the voltages necessary for instrument operation. The discussion of these hybrid sections in Section III of this manual will be helpful in maintenance and servicing.

4-13. TROUBLE LOCALIZATION.

4-14. Gaining Access To Internal Components. To gain access to internal components of the instrument, remove the top and bottom covers by removing the securing screw at the rear of each cover and then sliding the cover to the rear. Figure 4-1 shows the location of all major assemblies. To gain access to these assemblies, proceed as follows:

a. **Input Module.** To gain access to the input module, remove four screws (one in each corner) and lift off the cover.

b. **Display Module.** To gain access to the display module, pry off the two black plastic side trim strips, remove the four screws that secure the front top and bottom trim strips, and remove the top and bottom trim strips and front panel.

c. **Power Reference.** The power reference is secured to the front subpanel with two screws entering from the rear. To gain access to the power reference, follow the same procedure as for the display module.

4-15. Visual Inspection. With the instrument covers removed, inspect all assemblies for foreign material, unseated integrated circuits, transistors or connectors, broken leads, scorched components, loose screws, and other evidence of electrical or mechanical malfunction.

4-16. Use of Block Diagrams. By studying the detailed theory of operation in Section III together with the associated block diagrams, it may be possible to isolate the cause of an instrument malfunction to a particular block.

4-17. Systematic Troubleshooting. If visual inspection and block diagram analysis do not localize the source of a malfunction, proceed with module troubleshooting as follows:

a. **Power Supply.** With normal input power applied to the instrument, check the power supply output voltages at each module power connector. Correct power supply voltages are shown on the applicable schematic diagrams. If an abnormal voltage is encountered, disconnect the module connector from the module and note whether the power supply output voltage becomes normal; if it does, the problem probably is not in the power supply. If, on the other hand, the abnormal voltage condition remains, work backward through the power supply circuits, comparing voltages and waveforms with those shown in Figure 4-2. By analyzing abnormal indications, it should be possible to localize the problem to one component in the power supply.

b. **Input Module.** With a 2.51 mW signal applied to the power sensor, compare waveforms and voltages with those shown in Figure 4-3. Correct indications will essentially eliminate the input module as the source of an instrument malfunction; however, incorrect indications will not necessarily localize the problem to the input module because the input module depends on proper operation of the control module for such functions as ranging, analog-to-digital conversion, and recorder and meter output. If incorrect indications are obtained, localization of the problem using the oscilloscope and digital multimeter may be a long and tedious process; a simpler approach may be to proceed with signature analysis.

c. **Display Module.** Proper operation of the display module is generally self-evident. Incorrect operation does not necessarily mean that the problem is in the display module; the control module may be malfunctioning. The simplest and quickest way to check the display module is to perform the visual and signature analysis checks specified in paragraph 4-20.

d. **Control Module.** If normal indications are obtained in checking the power supply, input, and display modules, the problem must be in the control module; however, it is very unlikely that this situation will occur because it is virtually impossible for the input and display

modules to operate properly if the control module is malfunctioning. Signature analysis is the best way to localize a problem in the control module.

4-18. SIGNATURE ANALYSIS FREE-RUNNING TEST PROCEDURES.

4-19. To make free-running signature analysis tests, proceed as follows:

CAUTION

Make sure that power is off before attempting to perform steps a, b, and f of the following procedure. Failure to observe this caution may result in the loss or destruction of data stored in the non-volatile RAM.

NOTE

Prior to any signature analysis checks, note and record bit switch (Figures 4-1 and 4-3) settings. Restore these switch settings upon completion of the signature analysis tests.

a. **With power off,** remove the data bus connector P1 on the control board from socket J1 adjacent to J2, and remove the data bus connector P1 on the control board from socket J1 adjacent to IC2 and disconnect jumper from connector J5. (See Figure 6-5.) Do not remove any of the control board PROMs.

b. Detailed information for each of the free-running tests is provided in Tables 4-2 through 4-7. For each check, set the signature analyzer controls and make signature analyzer connections as specified in the applicable table.

NOTE

For instruments containing PROMs with codes differing from those referred to in the various signature analysis tables contact the Boonton Service Department for correct signatures.

c. After setting and connecting the signature analyzer, apply power to the instrument, touch the signature analyzer probe to the specified measurement points, and compare the signature obtained on the signature analyzer with that specified in the table. An incorrect signature is evidence of malfunction.

d. If an incorrect signature is noted, try replacing the integrated circuit(s) most intimately associated with the point at which the incorrect signature was obtained. For example: an incorrect signature in the address field would point to integrated circuit IC3 on the control board, but the problem could be caused by any other integrated circuit or component tied to that address line.

e. A signature of 0000 is obtained with the signature analyzer probe connected to common (ground). Some other items which will produce this signature are:

1. A node stuck at zero
2. A node at the signature analyzer clock frequency.

f. A signature of 755U is obtained with the signature analyzer probe connected to +5 volts. Some other items that will produce this signature are:

1. A node stuck at logic 1
2. Any signal with a specific relationship to the clock signal; if the clock signal is signal $\overline{RD}$ from the microprocessor, signals $\overline{IORQ}$, $\overline{WR}$, and $\overline{RFSH}$ are examples of signals that will produce this signature.

g. Upon completion of the free-running checks, *turn power off.* Then, reinstall data bus connector P1 in socket J1 on the control board and reinstall jumper at connector J5.

NOTE

If programmed tests are to be performed, leave jumper disconnected from connector J5.

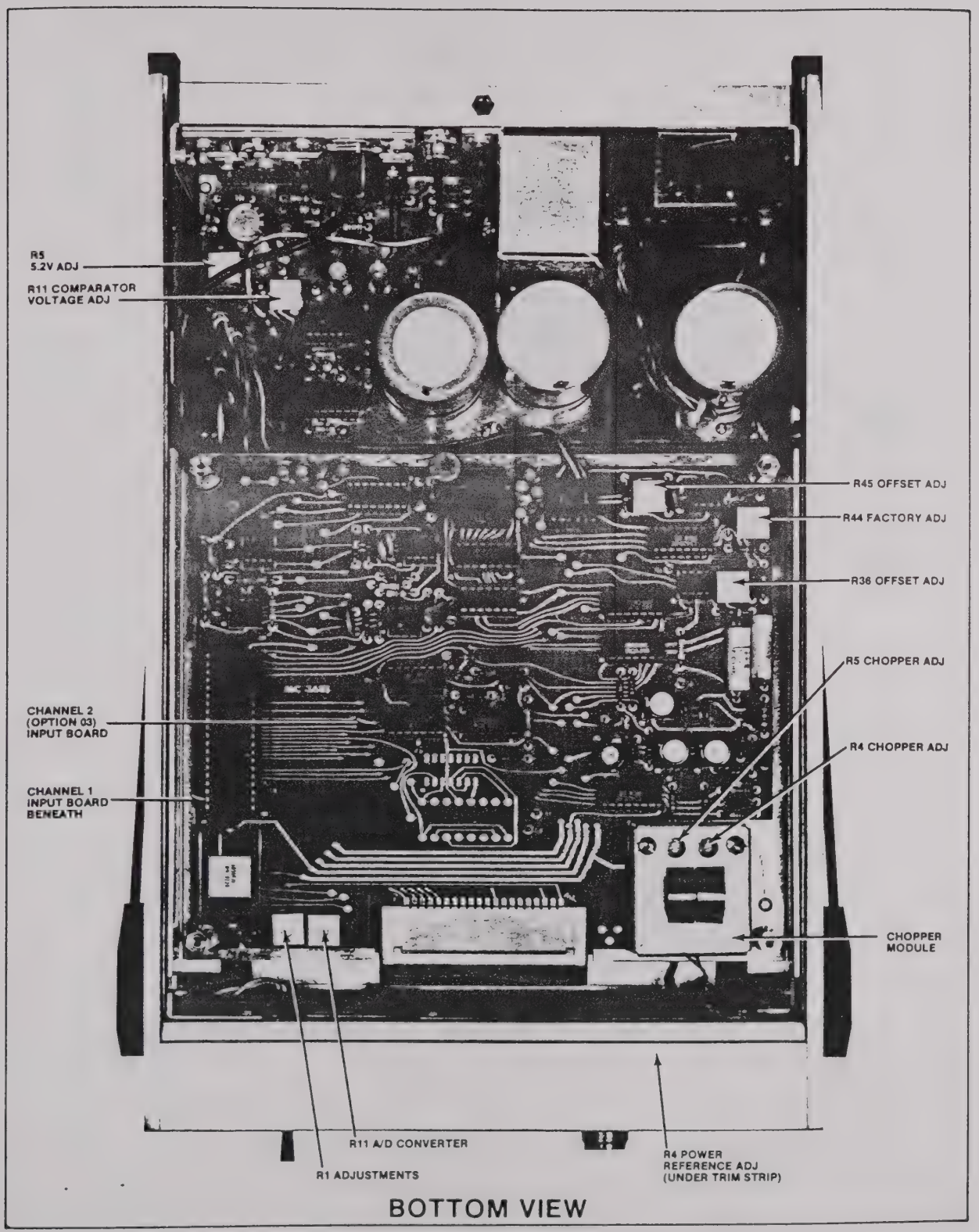


Figure 4-1 Location of Major Assemblies (Sheet 1 of 2)

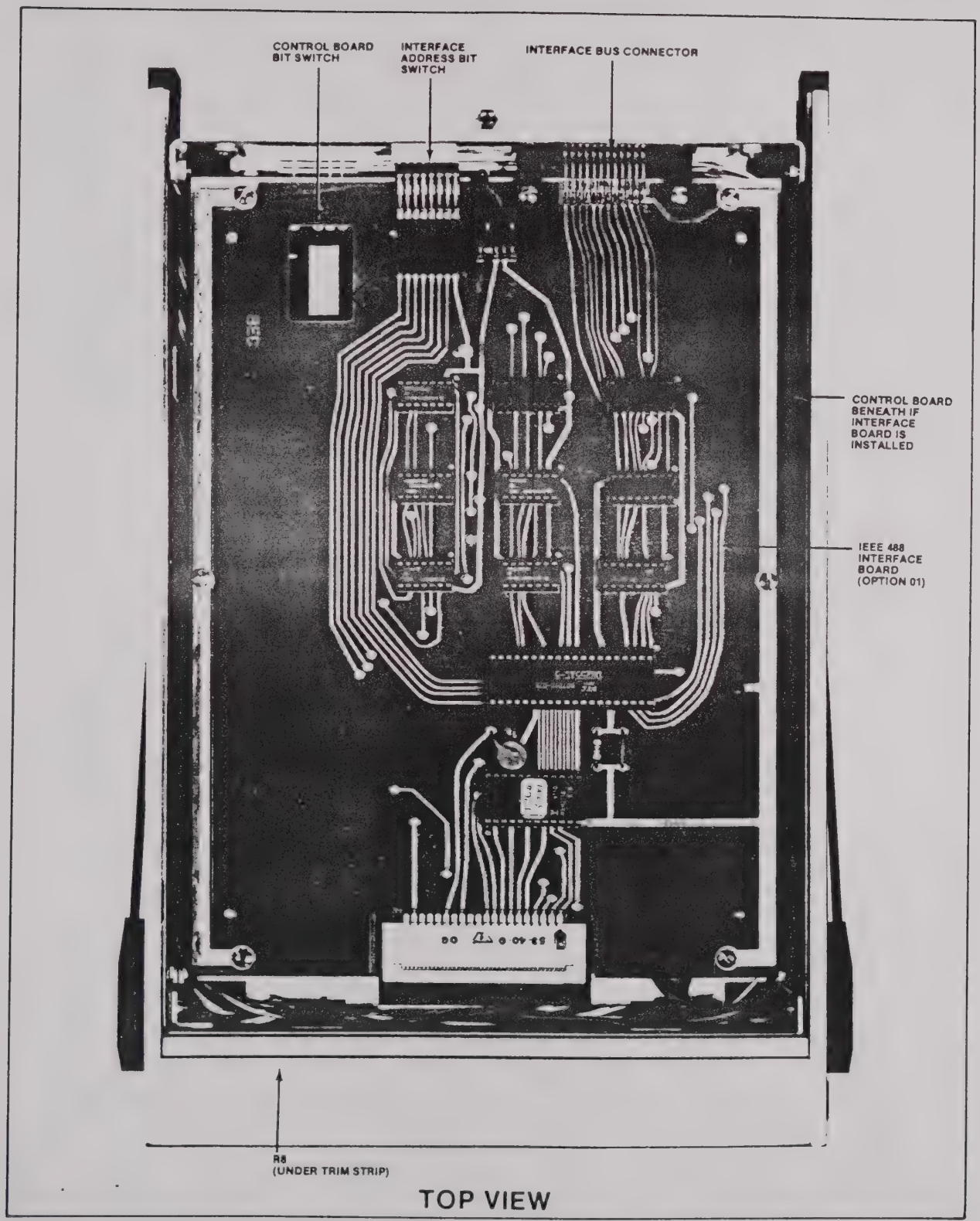

CONTROL BOARD BIT SWITCH
INTERFACE ADDRESS BIT SWITCH
INTERFACE BUS CONNECTOR
CONTROL BOARD BENEATH IF INTERFACE BOARD IS INSTALLED
IEEE 488 INTERFACE BOARD (OPTION 01)
R8 (UNDER TRIM STRIP)
TOP VIEW

Figure 4-1 Location of Major Assemblies (Sheet 2 of 2)

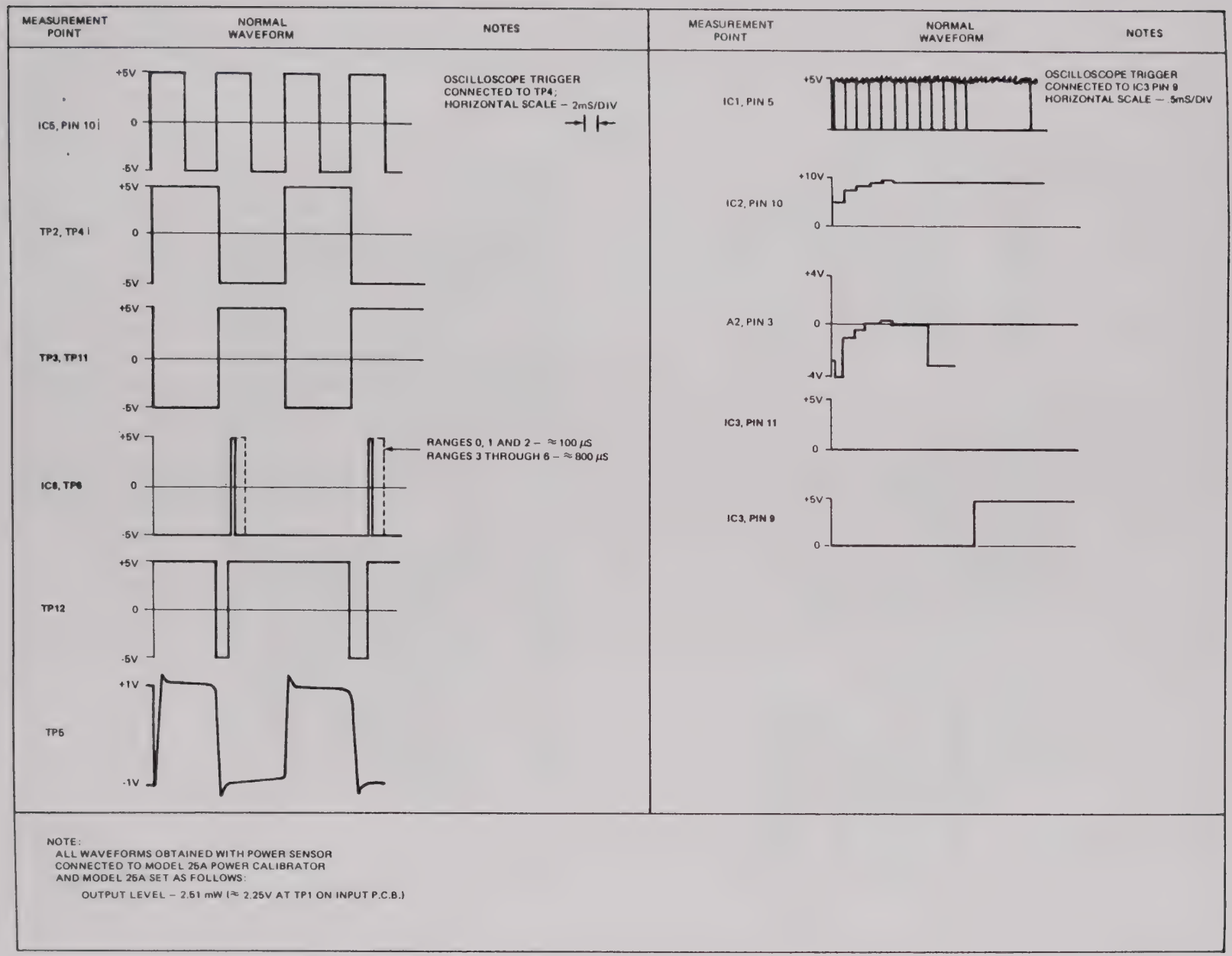
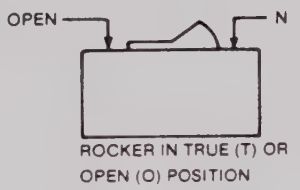
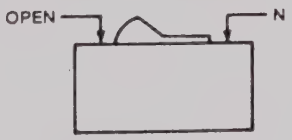


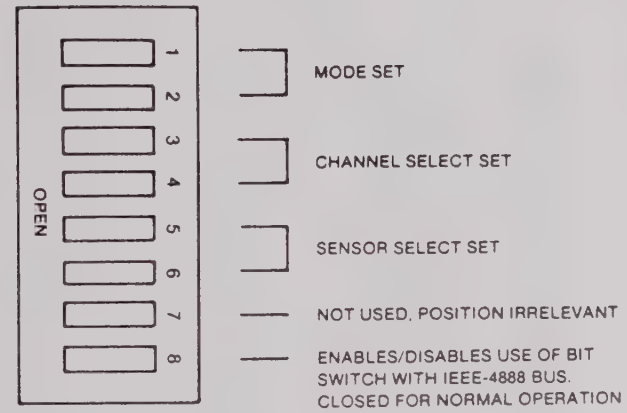
Figure 4-2 Input P.C. Board, Voltage and Waveform Data



ROCKER IN TRUE (T) OR
OPEN (O) POSITION



ROCKER IN FALSE (F) OR
CLOSED (C)



SWITCH SETTING								COMMENT
8	7	6	5	4	3	2	1	
ALWAYS CLOSED	NOT USED							
						C	C	OPERATE MODE
						C	O	CALIBRATE MODE 1 (DC CAL.)
						O	C	CALIBRATE MODE 2 (AC CAL.)
				C	O			ONE CHANNEL OPERATION
				O	O			TWO CHANNEL OPERATION
		C	C					ONE SENSOR CAPABILITY
		C	O					TWO SENSOR CAPABILITY
		O	C					THREE SENSOR CAPABILITY
		O	O					FOUR SENSOR CAPABILITY

THE ACTUAL SWITCH SETTING WILL BE A COMBINATION OF THE ABOVE.

Figure 4-3 Control Board Bit Switch Settings

TABLE 4-2. CONTROL BOARD ADDRESS FIELD TEST*

Signature Analyzer Function	Switch Setting	Connection Point	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP1				
STOP	⌐	TP1				
CLK	⌐	TP5				
			Any setting		Common	0000
					+5V	755U
				A0	IC3, pin 30	H335
				A1	IC3, pin 31	C113
				A2	IC3, pin 32	7050
				A3	IC3, pin 33	0772
				A4	IC3, pin 34	C4C3
				A5	IC3, pin 35	AA08
				A6	IC3, pin 36	7211
				A7	IC3, pin 37	A3C1
				A8	IC3, pin 38	7707
				A9	IC3, pin 39	577A
				A10	IC3, pin 40	HH86
				A11	IC3, pin 1	89F1
				A12	IC3, pin 2	AC99
				A13	IC3, pin 3	PCF3
				A14	IC3, pin 4	1180
				A15	IC3, pin 5	755U

*This test checks the output of the proper address field by CPU IC3; however, any item connected to an address line could be responsible for an incorrect signature on that line.
**0 = open

TABLE 4-3. CONTROL BOARD MEMORY DECODING TEST*

Signature Analyzer Function	Switch Setting	Connection Point	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP1				
STOP	⌐	TP1				
CLK	⌐	TP5				
			Any setting		Common	0000
					+5V	755U
				$\overline{CS0}$	IC4, pin 1	226U
				$\overline{CS1}$	IC4, pin 2	7CAP
				$\overline{CS2}$	IC4, pin 3	U469
				$\overline{CS3}$	IC4, pin 4	736P
				$\overline{CS4}$	IC4, pin 5	P8A0
				$\overline{CS5}$	IC4, pin 6	4HUU
				$\overline{CS6}$	IC4, pin 7	967U
				$\overline{CS7}$	IC4, pin 9	98C9
				$\overline{CS0\text{-}1}$	IC5, pin 6	2F9P
				$\overline{CS2\text{-}3}$	IC5, pin 3	U258
				$\overline{CS6\text{-}7}$	IC5, pin 11	7C99

*This test checks decoding for selection of memory integrated circuits.
**0 = open

TABLE 4-4. CONTROL BOARD I/O DECODING TEST*

Function	Signature Analyzer Switch Setting	Connection Point	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP1				
STOP	⌐	TP1				
CLK	⌐	TP5				
			Any settings		Common	0000
					+5V	755U
				$\overline{CS0}$	IC14, pin 1	17UH
				$\overline{CS1}$	IC14, pin 2	7375
				$\overline{CS2}$	IC14, pin 3	253H
				$\overline{CS3}$	IC14, pin 4	8059
				$\overline{CS4}$	IC14, pin 5	PAOU

*This test checks decoding for selection of I/O integrated circuits.
**O = open

TABLE 4-5. CONTROL BOARD ROM 0 TEST* (ROM F0G$_a$)

Function	Signature Analyzer Switch Setting	Connection Point	Bit Switch 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP7				
STOP	⌐	TP7				
CLK	⌐	TP5				
			Any setting		Common	0000
					+5V	7A70
				D0	IC6, pin 9	998H
				D1	IC6, pin 10	6144
				D2	IC6, pin 11	U628
				D3	IC6, pin 13	8HOC
				D4	IC6, pin 14	UUAC
				D5	IC6, pin 15	24FP
				D6	IC6, pin 16	C8U1
				D7	IC6, pin 17	2567

*This test checks the program content of ROM 0.

TABLE 4-6. CONTROL BOARD ROM 1 TEST* (ROM F1G$_a$)

Function	Signature Analyzer Switch Setting	Connection Point	Bit Switch 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP 19				
STOP	⌐	TP 19				
CLK	⌐	TP5				
			Any setting		Common	0000
					+5V	7A70
				D0	IC7, pin 9	32H8
				D1	IC7, pin 10	3A89
				D2	IC7, pin 11	P406
				D3	IC7, pin 13	C6PA
				D4	IC7, pin 14	3F85
				D5	IC7, pin 15	6965
				D6	IC7, pin 16	4F4F
				D7	IC7, pin 17	674H

*This test checks the program content of ROM 1 (IC7).

TABLE 4-7. INTERFACE BOARD ROM 2 TEST* (ROM $F2G_a$)

Function	Signature Analyzer Switch Setting	Signature Analyzer Connection Point**	Bit Switch 1 2 3 4 5 6 7 8	Item	Measurement Point**	Signature
START		TP18				
STOP		TP18				
CLK		TP5				
			Any setting		Common	0000
					+5V	7A70
				D0	IC1, pin 9	C42P
				D1	IC1, pin 10	67PU
				D2	IC1, pin 11	H9HH
				D3	IC1, pin 13	9144
				D4	IC1, pin 14	U195
				D5	IC1, pin 15	73P7
				D6	IC1, pin 16	5111
				D7	IC1, pin 17	U53C

*This test checks the program content of ROM 2.
**Signature analyzer connection points are on control board; measurement points are on interface board.

4-20. SIGNATURE ANALYSIS PROGRAMMED TEST PROCEDURES.

NOTE

Perform the free-running signature analysis tests before proceeding with programmed tests.

4-21. Use the following general procedure for each of the specified programmed signature analysis tests:

NOTE

A Boonton Electronics model 950004 diagnostic PROM is required for the programmed signature analysis tests.

a. Turn off input power to the instrument.

b. Remove ROMs IC6 and IC7 from their socket on the control board, and remove ROM IC1 from its socket on the interface board (if option -01 is installed). (See Figures 6-5 and A-2.)

c. Install a Boonton Electronics model 950004 diagnostic PROM in the socket from which ROM IC6 was removed, being careful to observe pin 1 orientation.

d. Check to see that data bus connector P1 on the control board is installed in socket J1, and that the jumper is *disconnected* from connector J5.

e. Turn on input power to the instrument.

f. Perform the specific test procedures provided in Tables 4-8 through 4-23. For each of the programmed signature analysis tests, make signature analyzer connections and switch settings as listed in the appropriate table. Then, set the bit switch on the control board as specified, connect the signature analyzer probe to the specified measurement points, and compare the signatures obtained on the signature analyzer with those listed in the table.

g. Note that in each signature analysis test the signature analyzer probe is first checked on common (ground) and then on +5 volts. If the specified signatures are not obtained for these checks, do not proceed further; subsequent signatures cannot possibly be correct. Recheck all signature analyzer connections and switch settings.

h. Both visual and signature analysis tests are provided for the display and keyboard of the instrument. The visual check should be made first because it is fast and simple; if the visual check is satisfactory, the signature analysis test may be omitted.

i. If an incorrect signature is obtained at any point, replace the integrated circuit (or other active device) most intimately associated with the node at which the incorrect signature is obtained. All integrated circuits and transistors in the instrument are socket-mounted for easy removal and replacement. If the signature is still incorrect after all active devices have been checked, all passive devices connected to that node should be suspect.

j. At the completion of all tests, turn off power to the instrument, remove the Boonton Electronics model 950004 diagnostic PROM from the control board, and install ROMs IC6 and IC7 in their sockets on the control board, and ROM IC1 in its socket on the interface board, ensuring that proper pin 1 orientation is observed.

k. Restore the bit switch (Figure 4-4) to the settings recorded at the start of signature analysis tests.

l. Connect jumper to connector P5 on the control board.

TABLE 4-8. CONTROL BOARD 4ABIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point*	Bit Switch** 1	2	3	4	5	6	7	8	Item	Measurement Point	Signature
START	⌐	TP6											
STOP	⌙	TP6											
CLK	⌐	TP5											
			C	C	C	C	C	C	C	C		Common	0000
												+5V	0000
											PB0	J3, pin 1	0000
											PB1	J3, pin 2	0000
											PB2	J3, pin 3	0000
											PB3	J3, pin 4	0000
											PB4	J3, pin 5	0000
											PB5	J3, pin 6	0000
											PB6	J3, pin 7	0000
											PB7	J3, pin 8	0000
			O	C	C	C	C	C	C	C	PB0	J3, pin 1	4F7C
			C	O	C	C	C	C	C	C	PB1	J3, pin 2	4F7C
			C	C	O	C	C	C	C	C	PB2	J3, pin 3	4F7C
			C	C	C	O	C	C	C	C	PB3	J3, pin 4	4F7C
			C	C	C	C	O	C	C	C	PB4	J3, pin 5	4F7C
			C	C	C	C	C	O	C	C	PB5	J3, pin 6	4F7C
			C	C	C	C	C	C	O	C	PB6	J3, pin 7	4F7C
			C	C	C	C	C	C	C	O	PB7	J3, pin 8	4F7C

*This test checks operation of ports A and B of the control module I/O port; the function of the bit switch is checked collaterally.
**O = open; C = closed

TABLE 4-9. CONTROL BOARD 4CIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point*	Bit Switch** 1	2	3	4	5	6	7	8	Item	Measurement Point	Signature
START	⌐	TP6											
STOP	⌙	TP6											
CLK	⌐	TP5											
												Common	0000
												+5V	7C88
			O	C	C	C	C	C	C	O	PC0	IC16, pin 14	5437
											PC1	IC16, pin 15	CCA9
											PC2	IC16, pin 16	1788
											PC3	IC16, pin 17	7C88

*This test checks the operation of part of port C of the control board I/O port.
**O = open; C = closed

TABLE 4-10. CONTROL BOARD 4DIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point*	Bit Switch** 1	2	3	4	5	6	7	8	Item	Measurement Point	Signature
START	⌐	TP6											
STOP	⌙	TP6											
CLK	⌐	TP5											
												Common	0000
												+5V	58UA
			C	O	C	C	C	C	C	O	PC4	IC16, pin 13	0000①
											PC4	IC16, pin 13	C35P②

*This test checks the operation of part of port C on the control board I/O port.
**O = open; C = closed ① Line voltage = 120 volts ② Line voltage = 90 volts

TABLE 4-11. DISPLAY VISUAL TEST (ROM 950 004)

Bit Switch* 1 2 3 4 5 6 7 8	Instrument Display
O O C C C C C O	In succession: All zeros All ones through all nines All decimal points All left-most annunciators All left-most-1 annunciators All left-most-2 annunciators All right-most annunciators and - sign Repeat of the above

NOTE: If this visual check produces satisfactory results, there is no need to perform the associated signature analysis check.
* O = open; C = closed

TABLE 4-12. CONTROL BOARD DISPLAY TEST* (ROM 950 004)

Function	Signature Analyzer Switch Setting	Connection Point*	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	⌐	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	U211
			O O C C C C C O	D0	IC3, pin 14	U129
				D1	IC3, pin 15	20CU
				D2	IC3, pin 12	2H81
				D3	IC3, pin 8	8A94
				D4	IC3, pin 7	6CO3
				D5	IC3, pin 9	4A29
				D6	IC3, pin 10	76H1
				D7	IC3, pin 13	U3A3

*This test checks output of digital information to the display. The signature analysis gate in this test is quite lengthy (approximately 8 seconds); hold the signature analyzer probe on each test point for at least one complete window, approximately 20 seconds.
**O = open; C = closed

TABLE 4-13. CONTROL BOARD DISPLAY SCAN TEST*

Function	Signature Analyzer Switch Setting	Connection Point	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP4				
STOP	⌐	TP4				
CLK	⌐	TP8				
					Common	0000
					+5V	000U
			O O C C C C C O	S0	IC18, pin 32	0000
				S1	IC18, pin 33	0005
				S2	IC18, pin 34	0003
				S3	IC18, pin 35	000U

*This test checks the control board display I/O chip for output of encoded scan data.
**O = open; C = closed

TABLE 4-14. KEYBOARD VISUAL TEST*

Bit Switch** 1 2 3 4 5 6 7 8	Press Keyboard Key	Instrument Display
C C O C C C C O	MODE PWR	0
	RANGE AUTO	1
	LIMITS LO	2
	CAL FACTOR dB	3
	SELECT SENS	4
	dB REF LEVEL dB	5
	MODE dB	8
	RANGE HOLD	9
	LIMITS HI	10
	CAL FACTOR GHz	11
	SELECT CHNL	12
	CLR	13
	CHS	16
	5	17
	6	18
	7	19
	8	20
	9	21
	.	24
	0	25
	1	26
	2	27
	3	28
	4	29
	CAL	32
	ZERO	33

*This test is partly keyboard and partly control board because the I/O chip (IC18) for the display board resides on the control board.
**O = open; C = closed

TABLE 4-15. CONTROL BOARD RAM TEST*

Function	Signature Analyzer Switch Setting	Connection Point	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	⌙	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	2915
			O C O C C C C O	PB0	J3, pin 1	5PPA
				PB1	J3, pin 2	77UU
				PB2	J3, pin 3	5PPA
				PB3	J3, pin 4	77UU
				PB4	J3, pin 5	5PPA
				PB5	J3, pin 6	77UU
				PB6	J3, pin 7	5PPA
				PB7	J3, pin 8	77UU

*This test writes bit patterns into each byte of the RAM, reads each byte and outputs it to the test socket at the rear of the control board where it is checked with the signature analyzer probe. While not completely exhaustive, this test will disclose most RAM failures.
**O = open; C = closed

TABLE 4-16. INPUT MODULE, CHANNEL 1 0AIO Test*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START		TP6				
STOP		TP6				
CLK		TP5				
					Common	0000
					+5V	876P
			C O O C C C C O	PA0	IC1, pin 4	485P
				PA1	IC1, pin 3	1A33
				PA2	IC1, pin 2	F85P
				PA3	IC1, pin 1	5H7U
				PA4	IC1, pin 40	OFF1
				PA5	IC1, pin 39	F1OC
				PA6	IC1, pin 38	9091
				PA7	IC1, pin 37	4P81

*This test checks the operation of I/O port A of the input module; correct signatures depend on proper functioning of both the control board and the input module.
**O = open, C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-17. INPUT MODULE, CHANNEL 1 0BIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START		TP6				
STOP		TP6				
CLK		TP5				
					Common	0000
					+5V	876P
			O O O C C C C O	PB0	IC1, pin 18	485P
				PB1	IC1, pin 19	1A33
				PB2	IC1, pin 20	F85P
				PB3	IC1, pin 21	5H7U
				PB4	IC1, pin 22	OFF1
				PB5	IC1, pin 23	F10C
				PB6	IC1, pin 24	9091
				PB7	IC1, pin 25	4P81

*This test checks the operation of I/O port B of the input module; correct signatures depend on proper functioning of both the control board and the input module.
**O = open; C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-18. INPUT MODULE, CHANNEL 1 0CIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	¬	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	5064
			C C C O C C C O	PC0	IC1, pin 14	6UO1
				PC1	IC1, pin 15	671U
				PC2	IC1, pin 16	CFH2
				PC3	IC1, pin 17	121H

*This test checks the operation of part of I/O port C on the input module; correct signatures depend on proper operation of both the input module and the control board.
**O = open; C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-19. INPUT MODULE, CHANNEL 1 0DIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	¬	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	23HC
			O C C O C C C O	PB0	A5J3, pin 1	0000①
				PB0	A5J3, pin 1	7H97②

*This test checks part of I/O port C of the input module for channel 1.
**O = open; C = closed
***Signature analyzer connection points and measurement points are on the control board.
① Signature obtained with range calibrator connected to channel 1 input, and range calibrator set to zero and R_S = 500k, or with instrument sensor connected to power REF connector and POWER REF ON switch set to off.
② Signature obtained with range calibrator connected to channel 1 input, and range calibrator set to range 5 and R_S= 500k, or with instrument sensor connected to POWER REF connector and POWER REF ON switch set to on.

TABLE 4-20. INPUT MODULE, CHANNEL 2 1AIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	¬	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	876P
			C O C O C C C O	PA0	IC1, pin 4	485P
				PA1	IC1, pin 3	1A33
				PA2	IC1, pin 2	F85P
				PA3	IC1, pin 1	5H7U
				PA4	IC1, pin 40	OFF1
				PA5	IC1, pin 39	F1OC
				PA6	IC1, pin 38	9091
				PA7	IC1, pin 37	4P81

*This test checks the operation of I/O port A on input module 2. Correct signatures depend on the proper operation of both the control board and input module 2.
**O = open; C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-21. INPUT MODULE, CHANNEL 2 1BIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1	2	3	4	5	6	7	8	Item	Measurement Point	Signature
START	⌐	TP6											
STOP	⌙	TP6											
CLK	⌐	TP5											
												Common	0000
												+5V	876P
			O	O	C	O	C	C	C	O	PB0	IC1, pin 18	485P
											PB1	IC1, pin 19	1A33
											PB2	IC1, pin 20	F85P
											PB3	IC1, pin 21	5H7U
											PB4	IC1, pin 22	OFF1
											PB5	IC1, pin 23	F1OC
											PB6	IC1, pin 24	9091
											PB7	IC1, pin 25	4P81

*This test checks the operation of I/O port B of input module 2. Correct signatures depend on proper operation of both the control board and input module 2.
**O = open; C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-22. INPUT MODULE, CHANNEL 2 1CIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1	2	3	4	5	6	7	8	Item	Measurement Point	Signature
START	⌐	TP6											
STOP	⌙	TP6											
CLK	⌐	TP5											
												Common	0000
												+5V	5064
			C	C	O	O	C	C	C	O	PC0	IC1, pin 14	6UO1
											PC1	IC1, pin 15	671U
											PC2	IC1, pin 16	CFH2
											PC3	IC1, pin 17	121H

*This test checks the operation of part of I/O port C of input module 2. Correct signatures depend upon proper operation of both the control board and input module 2.
**O = open; C = closed
***Signature analyzer connection points are on the control board; measurement points are on input module board.

TABLE 4-23. INPUT MODULE, CHANNEL 2 IDIO TEST*

Function	Signature Analyzer Switch Setting	Connection Point***	Bit Switch** 1 2 3 4 5 6 7 8	Item	Measurement Point	Signature
START	⌐	TP6				
STOP	⌐	TP6				
CLK	⌐	TP5				
					Common	0000
					+5V	P951①
			O C O O C C C O	PB0	A5J3, pin 1	0000①
				PB0	A5J3, pin 1	7H97②

*This test checks part of I/O port C of the channel 2 input module.
**O = open; C = closed
***Signature analyzer connection points and measurement points are on the control board.
① Signature obtained with range calibrator connected to the channel 2 input, and range calibrator set to zero and Rs =500kΩ, or with instrument channel 2 sensor connected to POWER REF connector and POWER REF ON switch set to off.
② Signature obtained with range calibrator connected to the channel 2 input, and range calibrator set to range 5 and Rs =500kΩ, or with instrument channel 2 sensor connected to POWER REF connector and POWER REF ON switch set to on.

4-22. NON-VOLATILE RAM CIRCUIT TESTS.

4-23. Non-Volatile RAM Test. To test the non-volatile RAM, proceed as follows:

CAUTION

This test will destroy and overwrite instrument data stored in the non-volatile RAM, necessitating reloading of data. This test should be made as a last resort only, or if it has been determined that stored instrument data has already been lost or is faulty.

NOTE

Leave the Boonton Electronics diagnostic PROM installed on the control board as for the programmed signature analysis tests. Make sure that jumper P5 on the control board is connected to connector J5.

a. With power applied to the instrument, set all eight segments of the bit switch on the control board to the open position.

b. Observe the instrument LED display. The LED display should provide an error indication c c c c initially.

c. Turn the input power off, then back on. If the non-volatile RAM is operating properly, the instrument LED display will show 1111.

d. Repeat step c several times. The LED display should always show 1111, not the error indication.

e. Upon completion of this test, turn off input power to the instrument, remove the diagnostic PROM from the control board, and install integrated circuit IC6 in its socket on the control board, making certain that the correct pin 1 orientation is observed.

4-24. Non-Volatile RAM Battery Test. (See Figure 4-5.) To test the non-volatile RAM battery, proceed as follows:

CAUTION

The following test procedure must be adhered to strictly; otherwise, instrument data stored in the non-volatile RAM will be lost. Do not attempt to take measurements other than those specified. Take all necessary precautions to ensure that no terminals are shorted to another terminal or to common (ground).

a. Remove the three screws that secure the non-volatile RAM cover and remove the cover to gain access to the battery terminals.

b. Connect a digital multimeter between common and terminal 4 (Figure 4-5), ensuring that the battery is not shorted to ground at any time.

c. Observe the digital multimeter indication; it should be at least 5 volts with input power to the instrument turned off. If the indication is less than 5 volts, the battery is probably nearing the end of its useful life; replace the battery in accordance with the procedures in paragraph 4-25.

NOTE

The load imposed on the battery by the non-volatile RAM is 5.25 microamperes or less. With this load, the battery has a rated life of at least 100,000 hours, which is greater than 10 years.

4-25. Non-Volatile RAM Battery Replacement. (See Figure 4-4.) To replace the non-volatile RAM battery, proceed as follows:

CAUTION

The following battery replacement procedure must be adhered to strictly; otherwise, the data stored in the non-volatile RAM will be lost. The battery replacement procedure must be performed with input power applied to the instrument; loss of power with the battery disconnected will result in the loss of stored data. Use a UL approved soldering iron, which has its exposed parts grounded.

a. Make sure that input power to the instrument is turned on.

b. Disconnect the battery lead connected to instrument ground (1, Figure 4-4). Insulate this lead to prevent electrical contact with any other terminal or electrical part.

c. Disconnect the other lead (2) of the same cell, and remove the cell.

d. Disconnect the leads (3 and 4) of the other cell, and remove this cell.

e. Install a new cell in place of the cell removed in preceding step d. Observe cell polarity. Connect the cell leads to points 3 and 4 in Figure 4-4.

f. Insulate the negative lead of the other new cell, and install this cell in place of the cell removed in step c. Connect the positive lead of this cell to point 2 in Figure 4-4.

g. Remove the insulator from the negative lead, and connect the negative lead to point 1 in Figure 4-4.

h. If the LED in the non-volatile RAM circuit should glow, disconnect the cell lead from common terminal (1, Figure 4-4) promptly, and insulate this lead. Lighting of the LED indicates that a malfunction exists and heavy current is being drawn from the battery. Do not proceed until the problem has been corrected.

i. Perform the battery test specified in paragraph 4-24. The voltage indication for a new battery should be 5.6 to 5.9 volts.

j. Connect a DC voltmeter capable of making above-ground measurements (neither terminal connected to instrument common) across 100-ohm resistor R6 on the control board. With line power on, the voltmeter should indicate approximately 0 volt; with line power off, the voltmeter should indicate 525 microvolts or less.

k. Install the control board cover, and secure the cover with the three cover retaining screws.

4-26. INSTRUMENT ADJUSTMENTS.

4-27. General. Adjustment procedures are provided for the chopper, input, display, power supply and power reference boards. The control board requires no adjustments. For the locations of test points and adjustment controls, refer to the applicable diagrams in Section VI.

4-28. Power Supply Adjustments. With all power connectors in place, the instrument controls set for proper line operation, and with line voltage applied, make power supply adjustments as follows:

a. Connect the digital voltmeter between TP3 and common. Note the voltage indication; it should be 5.20

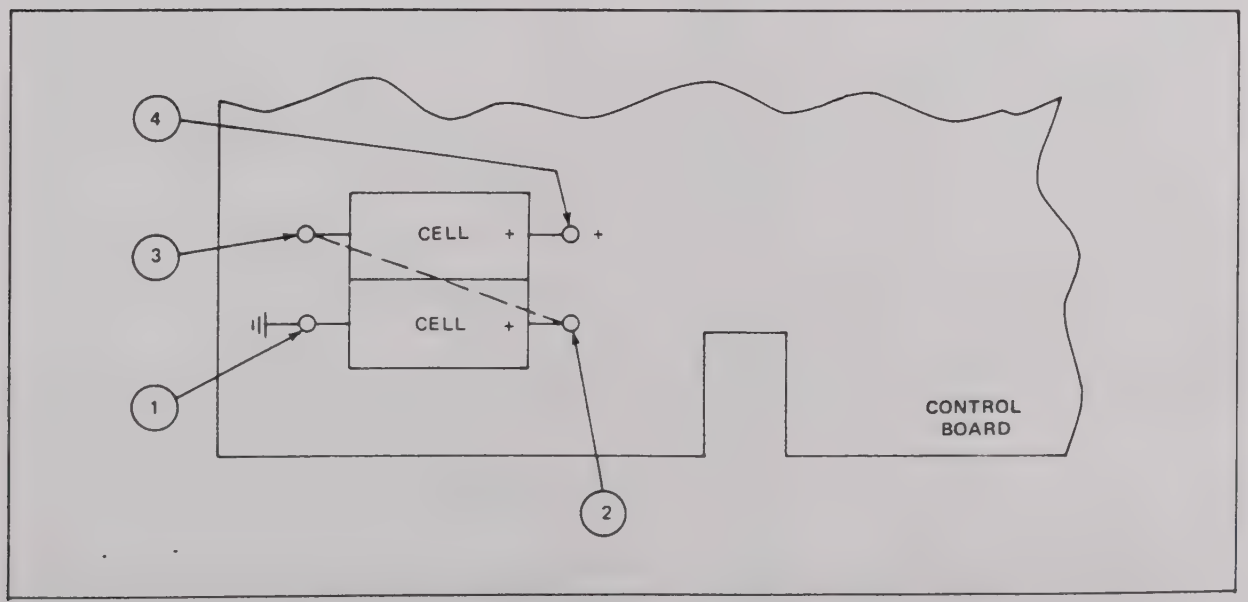


Figure 4-4 Non-Volatile RAM Battery Test and Connection Points

±0.002 Vdc. Adjust R5 as required to obtain the specified voltage.

b. Connect the digital voltmeter between TP2 and TP4. Note the voltage indication; it should be 150mV. ±10mV. Adjust R11 for an indication of 150mV. (The polarity of the reading will depend on how the test probes are connected to the circuit.)

c. Connect the digital voltmeter between TP1 and common. The voltage should be +15Vdc. ±0.6Vdc.

d. Connect the digital voltmeter between TP5 and common. The voltage should be -15Vdc. ±0.6Vdc.

e. Connect the digital voltmeter between TP6 and common. The voltage should be -5Vdc. ±0.2Vdc.

4-29. Input Module Adjustments. To adjust the input module, proceed as follows:

a. **Gaining Access to Adjustment Controls.** To gain access to input module adjustment controls, remove the four screws that attach the input module cover, and remove the cover. If the instrument is equipped with two input modules (option -03), the channel 2 input module will have to be removed temporarily to provide access to the channel 1 input module. The removal procedure for the channel 2 input module is as follows:

1. Remove the four channel 2 input module cover attaching screws, and remove the cover.
2. Remove the channel 2 chopper by unplugging it and positioning it out of the way.
3. Disconnect the voltage supply cable.
4. Disconnect the the 40-pin bus connector.
5. Remove the four screws that attach the channel 2 input module to the side frames of the instrument, and remove the channel 2 input module. Take care to ensure that no adjustments are disturbed.
6. Reverse steps 1 through 5 to install the channel 2 input module in the instrument.

b. **Offset Adjustments.** To perform input module offset adjustments, proceed as follows:

1. Turn on the instrument and the Model 2500 range calibrator, and allow the equipment to warm up for at least 30 minutes.
2. Connect the equipment as shown in Figure 4-5.
3. Set the instrument controls as follows:

(a) Set the control board bit switch for calibrate mode 1. (See Figure 4-3.)

(b) Press 1 and SELECT CHNL keys on the keyboard if the channel 1 input module is to be adjusted; press the 2 and SELECT CHNL keys if the channel 2 input module is to be adjusted.

(c) Press the MODE PWR key on the keyboard.

(d) Press the 0, RANGE HOLD, 0, and CAL FACTOR dB keys on the keyboard.

4. Set the range calibrator and controls to range 0 and 500kΩ source resistance, and press the ZERO button.
5. Connect a digital multimeter between test point TP9 on the input module and common.
6. Connect a clip lead from test point TP8 to chassis or common.
7. Connect a clip lead from test point TP7 to chassis or common.
8. Observe the digital multimeter indication; it should be less than ±15 millivolts. If the digital multimeter indication is incorrect, adjust potentiometer R45 as required to provide a digital multimeter indication of less than ±5 millivolts.
9. Remove the clip lead from test point TP8. The digital multimeter indication should be less than ±15 millivolts. If the digital multimeter indication is incorrect, adjust potentiometer R36 as required to provide a digital multimeter indication of less than ±5 millivolts.
10. Remove the clip lead from test point TP7.
11. Using the digital multimeter, measure the voltage at test point TP5. The voltage should be less than ±100 millivolts. If the voltage is incorrect, adjust potentiometer R24 as required to provide a voltage indication of less than ±100 millivolts.

NOTE

Potentiometer R24 is omitted in later instruments.

12. If no further adjustments are to be performed, set the control board bit switch back to operate mode. (See Figure 4-3.)

c. **Chopper Adjustment.** The preceding offset adjustments must have been completed before chopper adjustment is attempted. To perform the chopper adjustment, proceed as follows:

1. Allow the instrument to warm up for at least 30 minutes.
2. Connect the instrument and test equipment as shown in Figure 4-5.
3. Set the instrument controls as follows:

(a) Set the control board bit switch for calibrate mode 1. (See Figure 4-3.)

(b) Press the 1 and SELECT CHNL keys on the keyboard if the channel 1 chopper is to be adjusted; press the 2 and SELECT CHNL keys if the channel 2 chopper is to be adjusted.

(c) Press the MODE PWR key on the keyboard.

(d) Press the 0 and RANGE HOLD keys on the keyboard.

4. Set the range calibrator controls to range 0 and 500kΩ source resistance, and press the ZERO button.
5. Using the digital multimeter, measure the voltage at test point TP9 on the input module. Adjust potentiometer R4 and potentiometer R5 on the chopper board equally to obtain a reading from zero to -100 millivolts, but as close to zero as possible.

NOTE

Considerable fluctuation in the digital multimeter indications will be observed during the voltage measurements in the preceding step. The fluctuation is caused by noise, thermals, etc. Mental averaging of the indications will be required.

6. If no further adjustments are to be performed, set the control board bit switch back to operate mode. (See Figure 4-3.)

d. **A/D Converter Adjustment.** Conversion of voltage levels from analog to digital format is performed by the input module A/D converter, which operates in conjunction with the instrument microprocessor and appropriate software. There are two adjustments associated with the A/D converter: an upscale adjustment and a downscale adjustment. These adjustments have been made precisely during the instrument calibration process, and should seldom, if ever, require readjustment; however, if it is desired to check and readjust the A/D converter, the procedure is as follows:

NOTE

The input module offset and chopper adjustments should be completed before proceeding with the A/D converter adjustment.

1. Connect the instrument and test equipment as shown in Figure 4-5. Turn on the instrument and test equipment and allow a warmup period of at least 30 minutes.

2. Set the instrument controls as follows:

(a) Set the control board bit switch to calibrate mode 1. (See Figure 4-3.)

(b) Press the 1 and SELECT CHNL keys on the keyboard if the channel 1 input module is to be adjusted; press the 2 and SELECT CHNL keys on the keyboard if the channel 2 input module is to be adjusted.

(c) Press the MODE PWR key on the keyboard.

(d) Press the 0 and RANGE HOLD keys on the keyboard.

3. Set the range calibrator controls to range 0 and 500k source resistance, and press the ZERO button.

4. Zero the instrument by pressing the ZERO key on the keyboard.

5. Upon completion of the zeroing operation, press the 5 and RANGE HOLD keys on the keyboard.

6. Set the range calibrator to range 5 and release the ZERO button. The indication on the instrument LED display should be 3685. If the indication is incorrect, adjust potentiometer R1 on the input module as required to obtain the 3685 indication on the LED display.

7. Set the range calibrator to range 2. Press 2 and RANGE HOLD keys on the instrument and record the displayed reading.

8. Set the range calibrator to range 1 and adjust R11 for one tenth of the reading recorded on range 2. For example, if the range 2 display was 3680, set range 1 to display 368.

NOTE

If there is not enough range of R1 or R11, center R1 and R11 under the conditions of paragraph 6 above and adjust R11 to obtain a display of 3685 on range 5. Then repeat paragraphs 7 and 8 above. There is some interaction between R1 and R11, so recheck adjustments.

9. Set the control board bit switch back to OPERATE MODE. (See Figure 4-3.)

NOTE

Data has been entered into the non-volatile memory of the instrument at the factory for the instrument and for the sensor(s) ordered with the instrument. A copy of the factory-entered data is provided under the right side cover of the instrument. Field entry of data is not required unless stored data is destroyed or its accuracy becomes suspect, or if another sensor is to be used with the instrument.

4-30. DC CALIBRATION. The front end of the instrument input module is a balanced-input DC amplifier with seven decade ranges for nominal inputs of 10 microvolts to

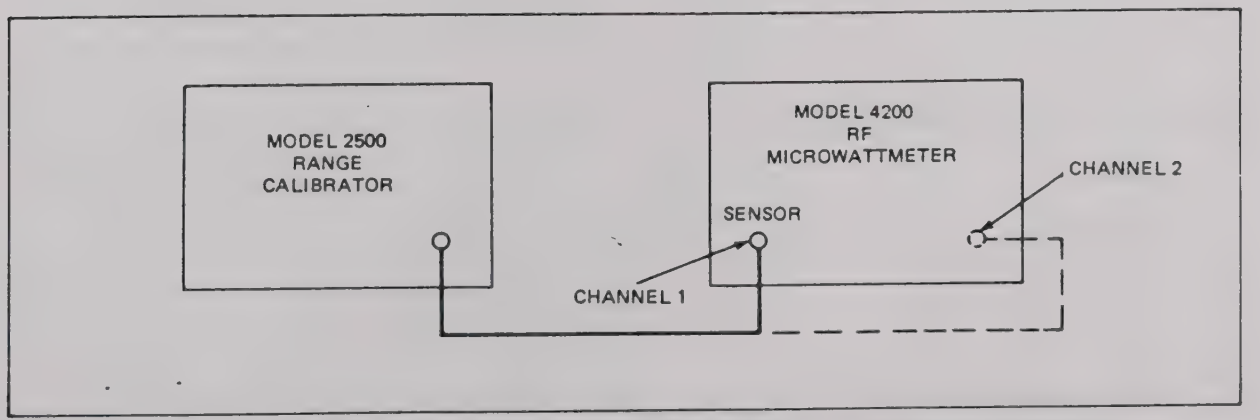


Figure 4-5 Test Setup for Input Module Offset, Chopper, and A/D Converter Adjustments

10 volts. The output is an unbalanced DC with a 2.5 volt full scale value for each range; this DC is converted into a proportional digital value. One manual gain adjustment, potentiometer R44, adjusts the gain of all ranges by the same amount; this adjustment is factory set during instrument calibration. Individual range adjustments are accomplished through software correction or adjustment, which is also determined during instrument calibration. The software corrections are stored in the instrument non-volatile memory. A gain factor associated with the recorder DC output is also stored in the memory. To calibrate the DC gain of the instrument, proceed as follows:

a. Connect the instrument and test equipment as shown in Figure 4-5.

b. Set the instrument controls as follows:

1. Set the control board bit switch to OPERATE MODE (see Figure 4-3).

2. Set the range calibrator to range 0 and depress ZERO.

3. Press the 1 and SELECT CHNL keys if channel 1 is to be adjusted; press the 2 and SELECT CHNL keys if channel 2 is to be adjusted.

4. Press the MODE PWR key.

5. Press the 0 and CAL FACTOR dB keys.

6. Press the 0 and dB REF LEVEL keys.

7. Press the ZERO key.

8. After zeroing is completed, set the control board bit switch to CALIBRATE MODE 1 and press, in order, the 1, 0, 0, 0, and RANGE AUTO keys.

9. Release the range calibrator ZERO.

10. Press the 0 and RANGE HOLD keys.

11. After allowing for a settling time, press in order the 3, 6, ., 8, 5, MODE dB, CAL, and dB REF LEVEL keys.

12. Line-by-line set the range calibrator and press the instrument keys as follows:

13. Disconnect the range calibrator and set the control board bit switch to OPERATE MODE.

4-31. AC CALIBRATION. Two types of data are stored in the instrument non-volatile memory for each sensor that is calibrated with the instrument: low-frequency gain corrections, and high-frequency gain corrections or calibration factors. (The calibration factors are marked on the sensor housing.) The low-frequency gain corrections are of two types: a gain factor for each range, and a gain correction for each range. Any sensor procured independently of the instrument must have its low-frequency gain data entered and stored in the non-volatile memory. Entry of high-frequency gain corrections is not absolutely necessary because calibration factors can be read from the sensor housing and entered through the instrument keyboard while using the instrument; however, if the capability of making automatic high-frequency gain corrections as a function of frequency is desired, high-frequency gain corrections must also be entered and stored in the instrument non-volatile memory. To calibrate the low-frequency gain of the instrument, proceed as follows:

NOTE

For all 4200-5 series sensors, increase all the levels indicated below by +10 dBm.

a. Connect the instrument and test equipment as shown in Figure 4-6.

NOTE

To calibrate with 4240 or 4241 sensors, the Model 25A must be replaced with an equivalent 50 MHz source.

b. Depress the Model 25A ZERO.

c. Set the control board bit switch to OPERATE MODE.

d. Press, in order, the 1, SELECT CHNL, sensor number of 1, 2, 3, or 4 as appropriate, SELECT SENS, 0, CAL FACTOR dB, 0, and dB REF LEVEL keys.

e. Set the control board bit switch to CALIBRATE MODE 1.

f. If calibrating a 4200-4 series sensor, press, in order, the 0, CAL FACTOR GHz, 1, 0, 0, 0, and CAL FACTOR dB keys.

Range Calibrator	Press	(Allow settling)	Press
Range 1	1, RANGE HOLD	—	CAL, dB REF LEVEL
Range 2	2, RANGE HOLD	—	CAL, dB REF LEVEL
Range 3	3, RANGE HOLD	—	CAL, dB REF LEVEL
Range 4	4, RANGE HOLD	—	CAL, dB REF LEVEL
Range 5	5, RANGE HOLD	—	CAL, dB REF LEVEL
Range 6A	6, RANGE HOLD	—	CAL, dB REF LEVEL

If calibrating a 4200-5 series sensor, press, in order, the 1, CAL FACTOR GHz, 1, 0, 0, 0, and CAL FACTOR dB keys.

If calibrating a 4240 sensor, press, in order, the 1, 3, 1, CAL FACTOR GHz, 3, 8, 5, 0, and CAL FACTOR dB keys.

If calibrating a 4241 sensor, press, in order, the 1, 3, 2, CAL FACTOR GHz, 3, 8, 5, 0, and CAL FACTOR dB keys.

g. Enter the four digit sensor serial number by pressing the appropriate keys followed by the LIMITS dB HI, 1, 0, 0, 0, and RANGE AUTO keys.

h. Set the control board bit switch to OPERATE MODE.

NOTE

For 4240 and 4241 sensors, go to paragraph ac.

i. Press the ZERO key.

j. After the zero cycle is completed, set the control board bit switch to CALIBRATE MODE 2.

k. Set the Model 25A for a -44 dBm output and release the zero button.

l. Press the 1 and RANGE HOLD keys and allow the display to settle. Then press the 3, 9, ., 8, 0, MODE dB, CAL, and dB REF LEVEL keys.

m. Set the control board bit switch to OPERATE MODE.

n. Press RANGE AUTO and MODE PWR keys. The display should read 039.8 nW. If it does not, reset the control board bit switch to CALIBRATE MODE 2 and press dB REF LEVEL. The display should read approximately 5000. Increase or decrease this number, depending on the direction of error from 039.8, by entering the new number that differs by approximately 10 counts. Reset the control board bit switch to OPERATE MODE. Now press RANGE AUTO and MODE PWR keys. The display should read 039.8 nW. Repeat this procedure until the displayed reading is correct. For example, if the two displayed values are 039.6 nW and 5270, press the 5, 2, 8, 0, and dB REF LEVEL keys. Reset the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 039.8 nW.

o. Set the control board bit switch to CALIBRATE MODE 2 and press the dB REF LEVEL key. Record the displayed value.

p. Press the 0 and RANGE HOLD keys. Allow the display to settle and then press the CAL and dB REF LEVEL keys. Enter the number stored from paragraph *o.* above and then press the dB REF LEVEL key.

q. Set the Model 25A for a -34 dBm output. Press 2 and RANGE HOLD keys, allow the display to settle, and then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE and press the RANGE AUTO and MODE PWR keys. The display should read 0.398 μW. If it does not, set the control board bit switch to CALIBRATE MODE 2, press dB REF LEVEL key and adjust the number higher or lower as in paragraph *n.* Repeat until 0.398 μW is obtained.

r. Set the Model 25A for a -40 dBm output. Set the control board bit switch to OPERATE MODE and press the RANGE AUTO and MODE PWR keys. The display should indicate 100.0 nW. Record this reading. If it does not, reset the control board bit switch to CALIBRATE MODE 2, press the LIMITS dB HI key and enter the difference between the recorded reading and 100.0 nW by pressing the appropriate keys. Repeat this procedure until a display of 100.0 nW is obtained.

For example, if the display originally reads 98.6 μW, the offset is 14 counts. After changing the control board bit switch to CALIBRATE MODE 2, the display is -0012. Press the LIMITS dB HI key followed by the numerical entry 2 (-12 + 2 = 14 counts). Reset the control board bit switch to OPERATE MODE and press the RANGE AUTO and MODE PWR keys. The display should now be 100.0 nW. Record the number stored in LIMITS dB HI.

s. Set the control board bit switch to CALIBRATE MODE 2. Press the 1 and RANGE HOLD keys, allow the display to settle, and enter the number recorded as stored in LIMITS dB HI in paragraph *r.* above. Press the LIMITS dB HI key.

t. Press the 0 and RANGE HOLD keys, enter the number recorded as stored in LIMITS dB HI in paragraph *r.* above, and press the LIMITS dB HI key.

u. Set the Model 25A for a -24 dBm output. Press the 3 and RANGE HOLD keys, allow the display to settle, and press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 03.98 μW. If it does not, adjust as in paragraph q above.

v. Set the Model 25A for a -30 dB output. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display

should read 1.000 μW. If it does not, adjust as in paragraph r above.

w. Set the Model 25A for a -14 dBm output. Set the control board bit switch to CALIBRATE MODE 2. Press the 4 and RANGE HOLD keys, allow the display to settle, and then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 039.8 μW. If not, adjust as in paragraph q above.

x. Set the Model 25A for a -20 dBm output. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 10.00 μW. If it does not, adjust as in paragraph r above.

y. Set the Model 25A for a 0 dBm output. Set the control board bit switch to CALIBRATE MODE 2. Press the 5 and RANGE HOLD keys, allow the display to settle, and press the 9, 9, ., 9, 9, MODE dB, CAL, and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE and press the RANGE AUTO and MODE PWR keys. Display should read 1.000 mW. If it does not, adjust as in paragraph q above.

z. Set the Model 25A for a -10 dBm output. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 100.0 μW. If it does not, adjust as in paragraph r above.

aa. Set the Model 25A for a +10 dBm output. Set the control board bit switch to CALIBRATE MODE 2. Press the 6 and RANGE HOLD keys, allow the display to settle, and then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE and press the RANGE AUTO and MODE PWR keys. The display should read 10.00 mW. If it does not, adjust as in paragraph q above.

ab. Set the control board bit switch to OPERATE MODE and repeat the AC calibration procedure of section 4-31 for all other sensors.

NOTE

The following steps apply only to the AC calibration of 4240 and 4241 series sensors. For 4241 series sensors, all levels should be +10 dBm higher than indicated.

ac. Connect the instrument and test equipment as shown in Figure 4-6. Substitute an equivalent 50 MHz source for the Model 25A Calibrator.

ad. Turn the source to OFF and press the instrument ZERO key. After the zero cycle is completed, set the control board bit switch to CALIBRATE MODE 2.

ae. Set the source for a 10 μW output.

af. Press the 0 and RANGE HOLD keys. Allow the display to settle. Then press the 9, 9, ., 9, 9, MODE dB, CAL, and dB REF LEVEL keys.

ag. Set the control board bit switch to OPERATE MODE.

ah. Press the RANGE AUTO and MODE PWR keys. The display should read 10.00 μW, averaged. If it does not, set the control board bit switch to CALIBRATE MODE 2. Press the dB REF LEVEL key. The display should read approximately 5000. Increase or decrease this value by 10 counts in the same direction as the error and press the dB REF LEVEL key. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 10.00 mW, averaged. Repeat this procedure until the proper indication is obtained.

EXAMPLE: The display reads 09.95μW. After setting the control board bit switch to CALIBRATE MODE 2 and pressing the dB REF LEVEL keys, the display reads 5270. Press the 5, 2, 8, 0, and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 10.00 μW.

ai. Set the source for a 2.51 μW output.

aj. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 02.51 μW. Record this setting. If it does not, set the control board bit switch to CALIBRATE MODE 2. Press LIMITS dB HI and enter number offset.

EXAMPLE: The display reads 02.41 μW. The offset is 10 counts from 02.51 μW. After setting the control board bit switch to CALIBRATE MODE 2 and pressing the LIMITS dB HI key, the display reads -0002. Press the 8 and LIMITS dB HI keys (-2 and +8 = 10 counts). Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should now read 02.51 μW. Repeat this procedure until the proper indication is obtained.

ak. Set the source for a 100 μW output.

al. Set the control board bit switch to CALIBRATE MODE 2. Press the 1 and RANGE HOLD keys. Allow the display to settle. Then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE

MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 100.0 μW. If it does not, adjust as in step *ah*.

am. Set the source for a 25.1 μW output.

an. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 25.1 μW. If it does not, adjust as in step *aj*.

ao. Set the source for a 1.0 mW output.

ap. Set the control board bit switch to CALIBRATE MODE 2. Press the 2 and RANGE HOLD keys. Allow the display to settle. Then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 1.000 mW. If it does not, adjust as in step *ah*.

aq. Set the source for a 0.251 μW output.

ar. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 0.251 mW. If it does not, adjust as in step *aj*.

as. Set the source for a 10.00 mW output.

at. Set the control board bit switch to CALIBRATE MODE 2. Press the 3 and RANGE HOLD keys. Allow the display to settle. Then press the CAL and dB REF LEVEL keys. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 10.00 mW. If it does not, adjust as in step *ah*.

au. Set the source for a 2.51 mW output.

av. Set the control board bit switch to OPERATE MODE. Press the RANGE AUTO and MODE PWR keys. The display should read 2.51 mW. If it does not, adjust as in step *aj*.

aw. Set the source for no output.

ax. Set the control board bit switch to CALIBRATE MODE 2. Press the 4, RANGE HOLD, 0, dB REF LEVEL, 5, RANGE HOLD, 0, dB REF LEVEL, 6, RANGE HOLD, 0, and dB REF LEVEL keys.

ay. Set the control board bit switch to OPERATE MODE. Repeat the AC calibration for all sensors.

4-32. Display Board Recorder Output Adjustment. To check and adjust the recorder output, proceed as follows:

a. Connect the instrument and test equipment as shown in Figure 4-6.

b. Set the instrument controls as follows:

1. Press the MODE PWR key on the keyboard.
2. Press the RANGE AUTO key on the keyboard.
3. Press the 0 and CAL FACTOR dB keys on the keyboard.
4. Press the 0 and dB REF LEVEL dB keys on the keyboard.

c. Set the power meter calibrator output to 1 mW.

d. Check the indication on the LED display of the instrument. If the indication is not 1.000 mW, press the CAL key.

e. With 1.000 mW indicated on the LED display, check the indication on the digital multimeter; it should be 9.98 to 10.00 volts. If the indication is correct, proceed directly to step h; if the indication is incorrect, proceed to step f.

f. If the digital multimeter indication in preceding step e was incorrect, set the control board bit switch to CALIBRATE MODE 1 (see Figure 4-3) and press the LIMITS dB LO key on the keyboard. The LED display will show a gain modifier of approximately 3600. Calculate a revised gain modifier value to obtain the required correction. For example: if the digital multimeter indication were 9.96 volts (0.4% low) and the LIMITS dB LO key recalled a gain modifier of 3500, the revised gain modifier value would be:

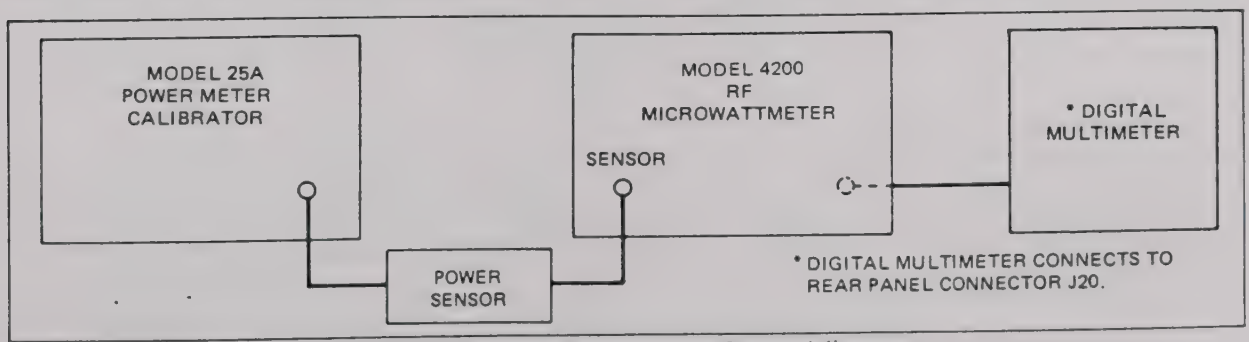


Figure 4-6 Test Setup for Recorder Output Adjustment

1.004 X 3500 = 3514.

Enter this revised gain modifier value by pressing the following keys on the keyboard:

3
5
1
4
LIMITS dB LO
LIMITS dB LO (revised value should appear on the LED display)

g. Reset the control board bit switch to OPERATE MODE 0. (See Figure 4-3.) Note the indication on the digital multimeter; it should be 9.98 to 10.00 volts. Repeat steps f and g, if necessary, until the correct indication is obtained.

h. Set the power meter calibrator output to 0.126 mW, and observe the indications on the instrument LED display and on the digital multimeter. The millivolt indication on the digital multimeter should equal ten times the value shown on the LED display ±1 count. If the digital multimeter indication is incorrect, remove the top trim strip from the instrument and adjust potentiometer R8 on the display board as required to provide the proper digital multimeter indication.

i. Repeat steps e through h until no further adjustment is necessary.

NOTE

Make sure that control board bit switch is set back to OPERATE MODE upon completion of the adjustments.

4-33. Power Reference Adjustment. To check and adjust the power reference output, proceed as follows:

a. Connect a 50-ohm test probe to a model EPM-1 milliwatt test set.

b. Turn on the milliwatt test set and the instrument. Set the POWER REF switch on the instrument to the ON position. Allow the milliwatt test set and the instrument to warm up for at least 30 minutes.

c. Standardize the milliwatt test set in accordance with the manufacturer's instructions.

d. Connect the probe of the milliwatt test set to the POWER REF connector of the instrument and note the indication on the milliwatt test set. The indication should be within ±0.005 dB.

NOTE

If the indication in step d is within the specified limits, no adjustment of the power reference is required. Proceed with the following steps only if the indication is outside the specified limits.

e. Remove the two black trim strips from the instrument by prying them free.

f. Remove the bottom front trip strip from the instrument by removing the two screws (one on each side) that secure the trip strip.

g. Locate the power reference adjustment. (See Figure 4-1.)

h. Adjust the power reference adjustment R4 as required to obtain an indication of 0 dBm +0.005 dB on the milliwatt test set.

i. Restandardize the milliwatt test set and recheck the power reference. Readjust the power reference adjustment as necessary.

j. Turn off the instrument and the milliwatt test set. Install the trim strips removed in steps e and f.

4-34. Entry of Sensor Calibration Factors Versus Frequency. Proceed as follows:

1. Using the keyboard keys, select the sensor for which calibration factors are to be entered. For example, if the calibration factors to be entered apply to sensor 4, press the 4 and SELECT SENS keys. Confirm correct sensor selection by again pressing the SELECT SENS key; the number of the selected sensor will appear on the instrument LED display.

2. Set the control board bit switch (Figure 4-3) to CALIBRATE MODE 2.

3. Press the 0 and RANGE AUTO keys, the 0 and CAL FACTOR GHz keys, and the 0 and CAL FACTOR dB keys.

4. Press the 1 and RANGE AUTO keys.

5. Using the keyboard keys, enter the frequency to which the sensor calibration factor to be entered applies. For example, if the sensor calibration factor to be entered applies to a frequency of 0.1 GHz, press the 0, ., and 1 numerical keys, then press the CAL FACTOR GHz key. (Frequencies of 0.1 GHz through 25 GHz are valid.)

NOTE

Frequencies must be in ascending order, starting with the lowest and advancing in sequence to the highest.

6. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 5. (For negative values, press the CHS key after entering the sensor calibration factor value.) After keying in the correct sensor calibration factor value, press the CAL FACTOR dB key. (Values of -1.25 to 1.25 are valid.)

NOTE

The following steps assume entry of the full complement of nine sensor calibration factors; if less than nine sensor calibration factors are to be entered, proceed until all entries have been made, and omit remaining steps except for the last two steps (31 and 32), which are mandatory in all cases.

7. Press the 2 and RANGE AUTO keys.

8. Using the numerical keys, enter the frequency (in GHz) to which the next sensor calibration factor to be entered applies; then press the CAL FACTOR GHz key.

9. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 8; then press the CAL FACTOR dB key.

10. Press the 3 and RANGE AUTO keys.

11. Using the numerical keys, enter the frequency to which the next sensor calibration factor to be entered applies; then press the CAL FACTOR GHz key.

12. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 11; then press the CAL FACTOR dB key.

13. Press the 4 and RANGE AUTO keys.

14. Using the numerical keys, enter the frequency to which the next sensor calibration factor to be entered applies; then press the CAL FACTOR GHz key.

15. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 14; then press the CAL FACTOR dB key.

16. Press the 5 and RANGE AUTO keys.

17. Using the numerical keys, enter the frequency to which the next sensor calibration factor to be entered applies; then press the CAL FACTOR GHz key.

18. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 17; then press the CAL FACTOR dB key.

19. Press the 6 and RANGE AUTO keys.

20. Using the numerical keys, enter the frequency to which the next sensor calibration factor to be entered applies; then press the CAL FACTOR GHz key.

21. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 20; then, press the CAL FACTOR dB key.

22. Press the 7 and RANGE AUTO keys.

23. Using the numerical keys, enter the frequency to which the next calibration factor to be entered applies; then press the CAL FACTOR GHz key.

24. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 23; then press the CAL FACTOR dB key.

25. Press the 8 and RANGE AUTO keys.

26. Using the numerical keys, enter the frequency to which the next calibration factor to be entered applies; then press the CAL FACTOR GHz key.

27. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 26; then press the CAL FACTOR dB key.

28. Press the 9 and RANGE AUTO keys.

29. Using the numerical keys, enter the frequency to which to next calibration factor to be entered applies; then press the CAL FACTOR GHz key.

30. Using the numerical keys, enter the sensor calibration factor for the frequency selected in step 29; then press the CAL FACTOR dB key.

31. Press the 0 and RANGE AUTO keys.

32. Reset the control board bit switch to OPERATE MODE.

4-35. SENSOR CALIBRATION.

4-36. General. In order to use a sensor for which calibration data is unknown, the following requirements must be met:

a. The control board bit switch must be set to accept another sensor number without returning an error indication. Data is stored in the instrument non-volatile memory for the number of sensors procured with the instrument; if a sensor number other than any of those for which data is stored is selected, an error message is displayed on the instrument LED display, thereby indicating an empty storage location. The control board bit switch is set to accept this number as the number of the sensor for which new data is to be entered, and the error

b. Serial number, type, and attenuation data for the new sensor must be entered into non-volatile memory.

c. Gain factors and gain corrections for the new sensor must be developed, entered, and checked. A calibration source is required for this function.

d. Calibration factors versus frequency, which are shown on the barrel of the sensor, must be entered into non-volatile memory.

4-37. Bit Switch Setting For Additional Sensor. To determine the correct bit switch setting for the new sensor, proceed as follows:

a. If the number of sensors for which data is already stored is unknown, select sensors in sequence through the keyboard until an error indication ([[02) appears on the instrument LED display. For example, press the 1 and SELECT SENS keys, the 2 and SELECT SENS keys, the 3 and SELECT SENS keys, and the 4 and SELECT SENS keys.

b. When an error indication is returned, press the SELECT SENS key a second time; if the LED display **does not** indicate the last selected sensor number, it can be assumed that no data has been entered in non-volatile memory for this sensor number.

c. Set the control board bit switch (Figure 4-3) to accept the sensor number that produced the error indication, and mark this sensor number on the sensor barrel.

4-38. Calibration of Model 4200-4C Sensor. The calibration procedures for this sensor are the same as those for other sensors, except that a 50-ohm to 75-ohm transformer is required between the power meter calibrator and the sensor. Any loss or gain introduced by the transformer must be taken into account during the calibration procedure. For example, if a transformer with a loss of 0.05 dB at 1 MHz is used, the LED display indications must be reduced by 0.05 dB while the input levels remain the same.

NOTE

When making final calibration checks of the sensor, the transformer loss in the example above can be compensated for by entering a calibration factor of +0.05 dB into the instrument.

4-39. DETERMINATION OF CALIBRATION FACTORS AND EFFECTIVE EFFICIENCY.

4-40. General. The calibration factors for sensors ordered with the instrument are entered into non-volatile memory at the factory. A calibration chart is also provided on the barrel of each sensor. It is not normally required to compute calibration factors unless a sensor is repaired or calibration factor data is suspect or lost. Paragraphs 4-41 and 4-42 provide instructions that can be used to determine calibration factors and effective efficiency; paragraph 4-43 provides instructions for more accurate determination of calibration factors.

4-41. Standard Calibration Factor Computation Method.

a. Connect the test equipment as shown in detail A, Figure 4-7.

b. Adjust the signal generator to the desired test frequency, and adjust its output level to a level sufficient to provide a stable indication on the **monitor** Model 4200.

c. Adjust the double stub tuner as required to obtain a peak indication on the **monitor** Model 4200..

d. Connect the equipment as shown in detail B, Figure 4-7.

e. At the same test frequency as used in step b, adjust the signal generator output level to provide a convenient indication on the standard power meter. Record the indicated power on the **monitor** Model 4200, and the power indication (P_s) on the standard power meter.

f. Connect the equipment as shown in detail C, Figure 4-7.

g. At the same test frequency as used in steps b and e, adjust the signal generator output level as required to obtain the same power indication on the **monitor** Model 4200 as recorded in step e. Record the indicated power (P) on the Model 4200 that is being calibrated.

h. Compute the calibration factor for the test frequency from the relationship:

$$k = \frac{\text{indicated power}}{\text{incident power}} = k_s \frac{(1 - e)P}{(1 - e_s)P_s}$$

Where:

k_s = calibration factor of standard power meter
e_s = instrumentation error of standard power meter for range used
P_s = indicated power on standard power meter
e = instrumentation error of Model 4200 for range used
P = indicated power on Model 4200

NOTE

It is important that the instrumentation error (e_s) of the standard power meter be known. This error can be determined by methods described by the manufacturer. In most cases, the uncertainty of the instrumentation error can be reduced by operating at higher power levels.

i. Repeat steps a through h for each of the other test frequencies of interest.

4-42. Measurement of Effective Efficiency.

a. Connect the equipment as shown in Figure 4-8.

b. Set the signal generator to the test frequency of interest and adjust its output level as required to provide a convenient indication on the Model 4200 that is to be calibrated and a sufficient indication of reflected power on the monitor Model 4200.

c. Record the incident and reflected power indications on the two Model 4200 instruments as value P_i and P_r, respectively. When recording these values, correct the indicated values to account for the two 6 dB attenuators.

d. Calculate the square of reflection coefficient $|\rho_\ell|^2$ of the Model 4200 being calibrated from the relationship:

$$|\rho_\ell|^2 = P_r/P_i$$

e. Calculate the effective efficiency from the relationship:

$$\eta = \frac{k}{1 - |\rho_\ell|^2} = \frac{\text{indicated power}}{\text{dissipated power}}$$

Where: k = calibration factor determined in paragraph 4-48.

4-43. Improved Calibration Factor Accuracy. The derivations for the equations relating to diode-type sensors are based on the premise that the full-wave rectifying circuit in the sensor is responsive to the total input voltage that appears across the internal impedance of the sensor. The extent that it fails to do so is accounted for in the calibration factor. The calibration factor for a power sensor should be determined using as nearly perfect a power source as possible, that is, one that generates a pure sine wave behind an impedance of Z_o, where Z_o is resistive and equal to the characteristic impedance of the measurement system (generally 50 ohms). With the use of leveling, the source impedance can be brought sufficiently close to the ideal to hold the degree of measurement uncertainty within acceptable limits. This uncertainty contributes, in part, to the specified accuracy of the Model 4200.

4-44. The accuracy of the calibration factor and effective efficiency can be improved if the complex reflection coefficients of the source and the power sensors are known. The values of indicated power for both the standard power

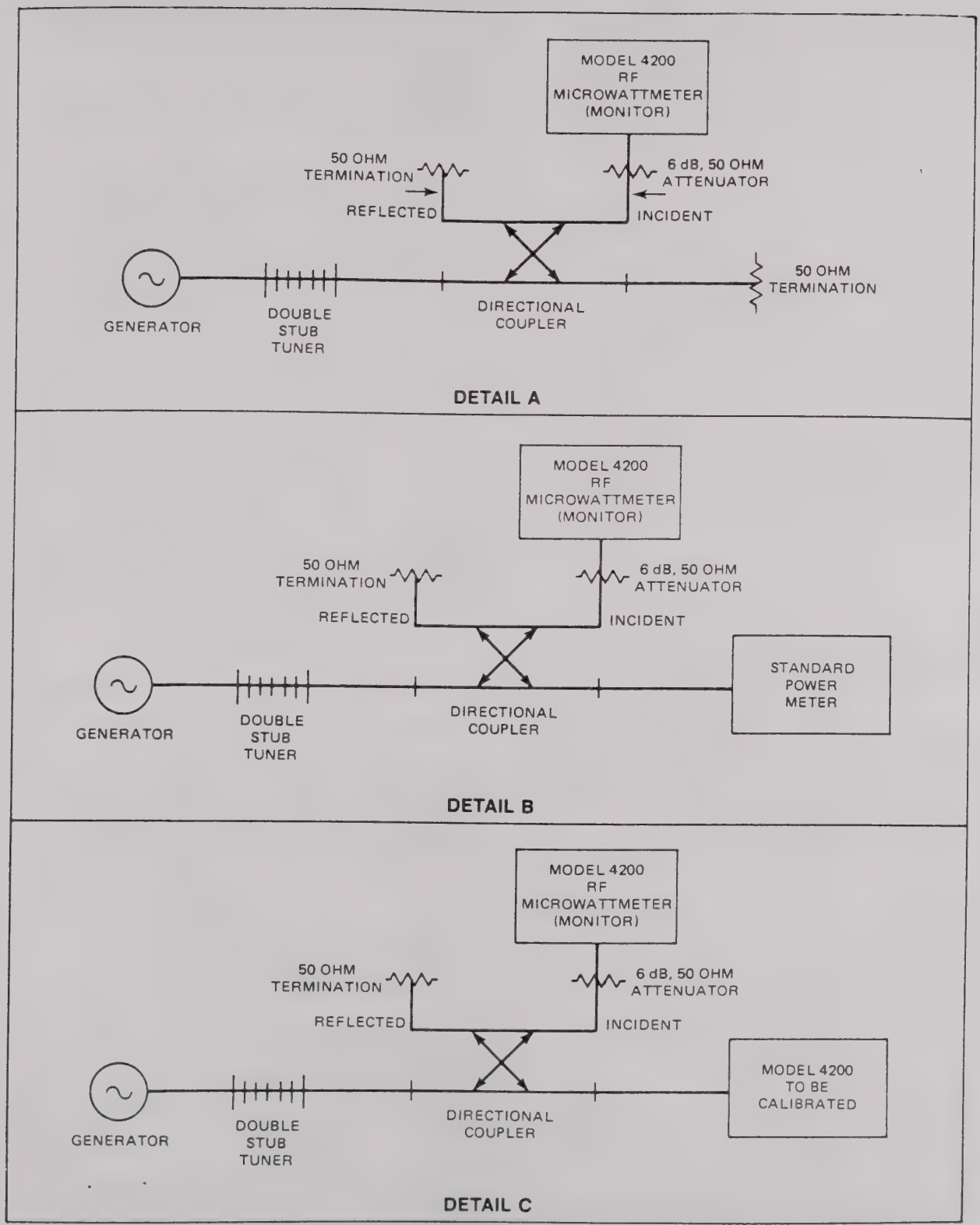


Figure 4-7 Calibration Factor Measurements, Test Setups

meter and the Model 4200 to be calibrated are obtained with measurements described in paragraph 4-41.

4-45. Terms used in the following calculations are defined as follows:

$Z_o = R_o + j0$ ohms
ρ_g = complex reflection coefficient of source
ρ_s = complex reflection coefficient of standard sensor
ρ_ℓ = complex reflection coefficient of test sensor
P_s = indicated power on standard power meter
P_{ds} = power dissipated in standard sensor
P_d = power dissipated in test sensor
P_i = incident power (from Z_o source)
P_o = power dissipated in a sensor of Z_o ohms
P = indicated power on meter to be calibrated
e_s = instrument error factor of standard meter
e = instrument error factor of test meter
k_s = calibration factor of standard sensor
k = calibration factor of test sensor
η_s = effective efficiency of standard sensor
η = effective efficiency of test sensor

4-46. If we let m equal the ratio of power dissipated in a sensor of Z_o ohms to the power measured with a diode-type power sensor, when each is connected, in turn, to a source with a reflection coefficient ρ_g, it can be shown that:

$$m = P_o/P_m = \frac{(1 + \rho_g\rho_\ell^2 - \rho_g\rho_\ell - \rho_\ell)^2}{(1 - \rho_\ell)^2} \qquad (1)$$

By definition,

$$k = P/P_i = \frac{\text{indicated power}}{\text{incident power}} = \text{calibration factor}$$

This relationship is correct provided that measurements are made with a Z_O source. The power obtained by dividing the indicated power by the calibration factor, when the Model 4200 is connected to an imperfect source, should be referred to as measured power P_m, where:

$$P_m = P/k \qquad (2)$$

Also, by definition:

$$\eta = P/P_d = \frac{\text{indicated power}}{\text{dissipated power}} = \text{effective efficiency}$$

$$k/\eta = P_d/P_i = \frac{\text{dissipated power}}{\text{incident power}} = (1 - |\rho_\ell|^2)$$

P_O is designated as the power that would be dissipated in a sensor of Z_O ohms if it was connected to a power source having a reflection coefficient of ρ_g. This power is related to the actual power dissipated in the standard sensor by:

$$P_o = P_{ds}\frac{|1 - \rho_g\rho_s|^2}{(1 - |\rho_s|^2)} \qquad (3)$$

Rearranging equation (2) to solve for k, and substituting for P_m with (1), yields:

$$k = m\,(P/P_O) \qquad (4)$$

4-47. Typical Example.

a. Using source number 1 of Figure 4-9, the following measurements obtain for the two power sensors shown:

1. **Standard Power Sensor.**
   P_s = indicated power = 49 μW
   P_i = incident power = 50 μW
   P_{ds} = dissipated power = $P_i\,(1 - |\rho_s|^2)$
   = 50 μW X 0.99
   = 49.5 μW

From this,

k = 49 μW/50 μW = 0.98

and,

η = 49 μW/49.5 μW = 0.99

2. **Diode-Type Power Sensor.**
   P = indicated power = 48 W
   P_i = incident power = 50 W
   P_d = dissipated power = $P_i\,(1 - |\rho_\ell|^2)$
   = 50 μW X 0.974
   = 48.7 μW
   k = 48 μW/50 μW = 0.96
   η = 48 μW/48.7 μW = 0.986

b. Using source number 2 of Figure 4-9, the following measurements obtain for the two power sensors shown:

1. **Standard Power Sensor.**
   P_s = 55.9 μW
   $P_{ds} = P_s/\eta$
   = 55.9 μW/0.99
   = 56.5 μW
2. **Diode-Type Power Sensor.**
   P = 55.6 μW

c. Assuming for convenience that the instrument errors are zero, the calibration factor of the test instrument would be computed from paragraph 4-41 to be:

k = 0.98(55.6 μW/55.9 μW) = 0.975

This is 1.6% higher than the actual value of k. When the complex reflection coefficients are known, however, using equations (1), (3), and (4), we find:

$$m = \frac{[1 + (0.106\ \angle 122^\circ)(0.16\ \angle -96^\circ)^2 - (0.106\ \angle 122^\circ)(0.16\ \angle -96^\circ) - (0.16\ \angle -96^\circ)]^2}{(1 - 0.16\ \angle -96^\circ)^2} \qquad (1)$$

$$m = 0.97$$

$$P_o = 56.5\ \mu W\ \frac{|1 - (0.106\ \angle 122^\circ)(0.099\ \angle -78.6^\circ|^2}{(1 - 0.099^2)} \qquad (3)$$

$$P_o = 56.5 \times 0.9946$$

$$P_o = 56.2\ \mu W$$

From this,

$$k = 0.97\,\frac{55.6}{56.2} = 0.96 \qquad (4)$$

This is the correct calibration factor determined in step a.2 using an ideal 50-ohm source.

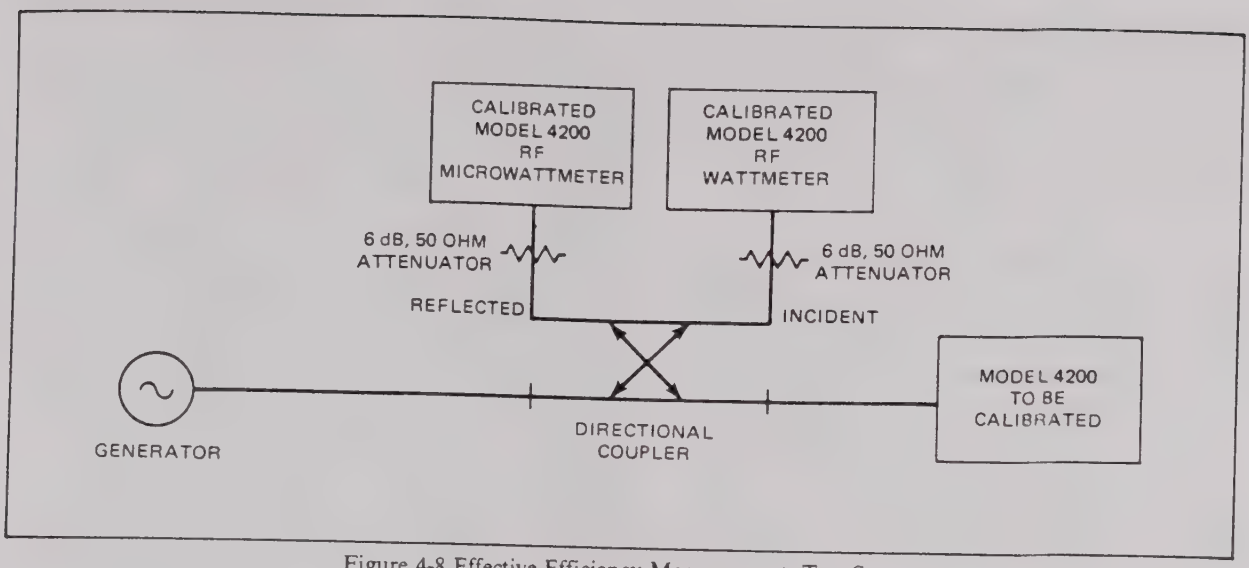


Figure 4-8 Effective Efficiency Measurement, Test Setup

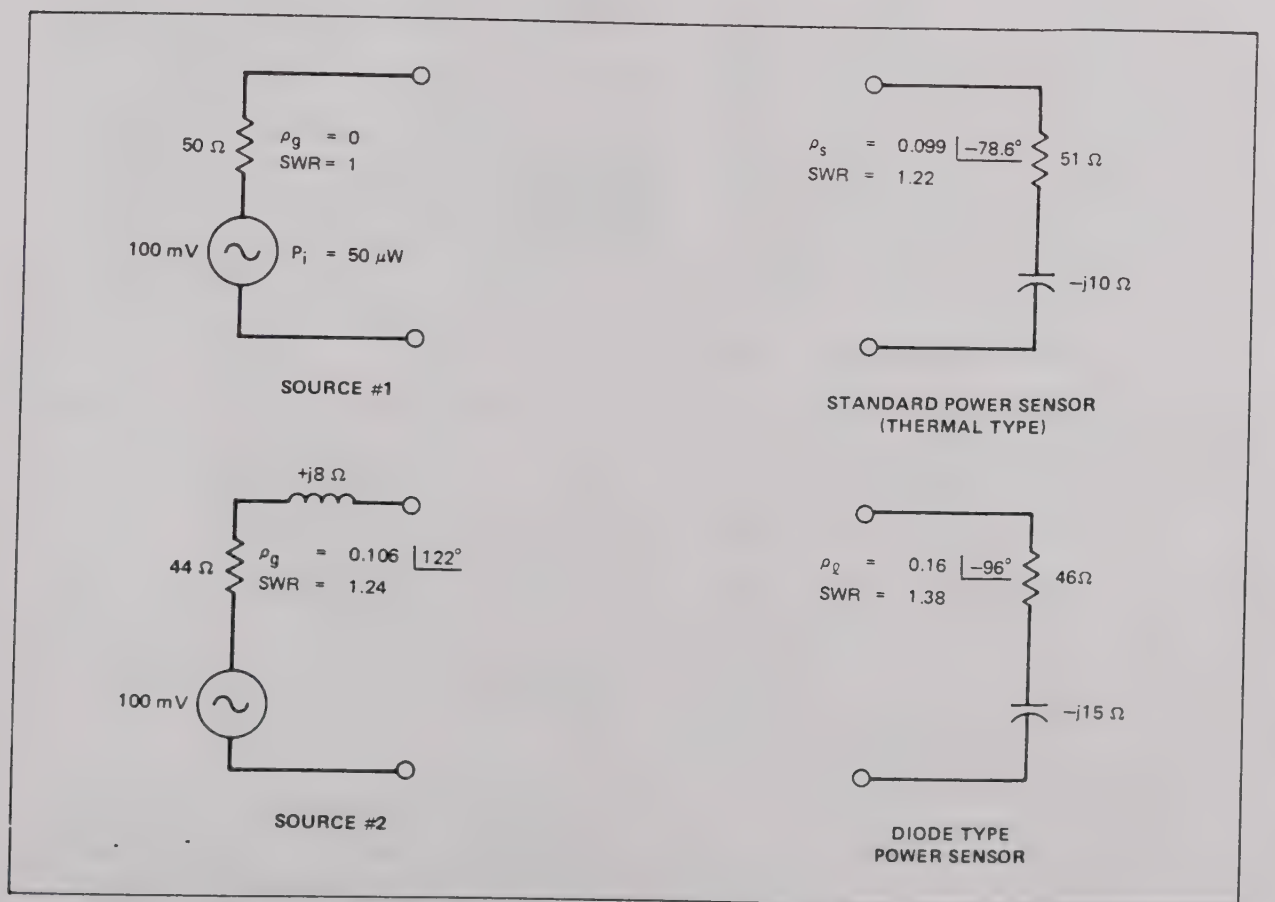


Figure 4-9 Source and Sensor Examples for Calibration Factor Measurements

4-48. HIGH FREQUENCY ACCURACY.

4-49. General. Power measurements, particularly at high frequencies, are fraught with a number of uncertainties. These include: what power is measured, what power it is desired to measure, and how the indicated power is converted to the needed power. If all power sources and power meters had impedances that were resistive and equal to Z_o (the characteristic impedance of the measuring system), most problems would disappear. The incident, dissipated, and maximum available powers would all be equal, and the indicated power would differ only by the inefficiency of the power sensor in converting all of the dissipated power to indicated power. This inefficiency is called the effective efficiency and, for a power sensor whose input impedance is resistive and equal to Z_o, it also defines the calibration factor. Unfortunately, perfect impedances are seldom the case and the source impedance of power sources can depart substantially from Z_o. The use of attenuator pads can mask this departure, as can the use of a directional coupler to level the source and reduce its reflection coefficient to a value equal to the directivity factor of the coupler. No such control over the input impedance of a power sensor is possible without the use of attenuator pads which sacrifice sensitivity and introduce other uncertainties.

4-50. Mismatch Error Correction Using Complex Relection Coefficients.
When the complex reflection coefficients of both an imperfect source and the power detector are known, a correction factor can be calculated and applied to the measured power, P_m, to obtain the power that would be dissipated in an ideal power sensor of impedance Z_o. The correction factor, m, equals:

$$m = \frac{P_d}{P_m} = \frac{1 + \rho_g\rho_l^2 - \rho_g\rho_l - \rho_l}{1 - \rho_l^2} \qquad (1)$$

where $P_m = \frac{P_{ind}}{K}$ = measured power

P_d = dissipated power
P_{ind} = indicated power
K = calibration factor
ρ_g = complex reflection coefficient of the power source
ρ_l = complex reflection coefficient of the power detector

The maximum power available from this source is:

$$P_a = \frac{P_d}{1 - |\rho_g|^2} \qquad (2)$$

4-51. Assume that the complex reflection coefficients are known to be $\rho_g = 0.0909 \angle 20°$ and $\rho_l = 0.111 \angle -35°$. The calibration factor for this power meter at the operating frequency is 1.138 (as determined from the incident power of a 50-ohm source). When the power meter and source are connected, the indicated power is 55.2 μW. Applying the calibration factor, $P_m = 55.2/1.138 = 48.5\ \mu W$. The correction factor calculated from equation (1) for the reflection coefficients given is 0.99; thus the power that would be dissipated in an ideal power meter would be 0.99 X 48.5 μW, or 48.0 μW. The maximum available power from this source, from equation (2), is $48.0/[1 - |0.0909|^2] = 48.4/\mu W$.

4-52. Mismatch Uncertainties Where Only SWR Is Known. When the complex coefficients of both an imperfect source and a power sensor are not known, and only the maximum or actual SWR of both are known, the maximum positive and negative uncertainties of the measured power, P_m, can be determined from Figure 4-10. In the example above, the SWR of the source is known to be 1.2 and the SWR of the power sensor is 1.25. From Figure 4-10, the power measured by an ideal power meter connected to the same source may differ by +2% from the power measured by the imperfect meter, from 47.5 μW to 49.5 μW. The maximum power available from this source is:

$$P_a = \frac{47.5}{0.99} = 47.9\ \mu W \text{ to } \frac{49.5}{0.99} = 49.9\ \mu W.$$

4-53. Where Neither Reflection Coefficients Nor SWR Are Known. When neither the complex reflection coefficients nor SWR of both an imperfect source and a power sensor are known, the measured power cannot be defined as anything except the indicated power. If, however, the power source impedance is Z_o, the calibration factor can be applied to yield the incident power. In the case of series 4200 power sensors, the calibration factor versus input frequency in GHz is shown on a decal on the power sensor.

4-54. POWER SENSOR REPAIR

4-55. Repair and adjustment of a Power Sensor is a difficult operation requiring a high degree of skill. If the user elects to make such a repair, it must be understood that the repaired Sensor may not meet the swr and response characteristics as specified in this manual.

4-56. Before attempting a repair of the Power Sensor check all possible sources of trouble, such as the instrument itself, the probe cable, connectors, the RF power source, etc. If the defect cannot be located, and the symptoms indicate a faulty Power Sensor, make the external resistance measurements outlined below to localize the trouble before opening the Sensor housing. (A Simpson Model 260 is recommended for most of these measurements.)

a. Measure the resistance of the RF input connector from the center conductor to ground shell. This should be 50, ±1 Ω. (For this measurement, a more accurate instrument than the Model 260 should be used.)

b. Inspect the rear connector for possible damage. Measure the resistance from pins 1 and 2 to ground. This should measure >10 MΩ.

c. With the Model 260 on the 10 kΩ range, measure the resistance from pin 1 (negative lead of the 260) to pin 2 (positive lead). This should be less than 3 kΩ.

d. With the Model 260 on the 10 kΩ range, measure the resistance from pin 1 (positive lead of the 260) to pin 2 (negative lead). This should be greater than 400 kΩ.

e. Remove the three 2-56 screws holding the outer shield. Slide the shield forward over the RF input connector.

f. Look for broken wires at this point. If any are found, repair them and retest the unit before proceeding.

g. The rear connector may be replaced, if necessary, by removing the set-screw at the side of the rear disc (the red mark on the side of the housing polarizes pin 1).

h. Remove the four 2-56 screws holding the inner shield. Slide the shield backwards from the main housing. Unsolder the wires at the teflon terminals, if necessary.

If the Power Sensor failed the insulation test in (b), look for a short to ground from the 1000 pF capacitors C102 and C103, or an internal short in one of the capacitors. These capacitors may be removed by taking out the two 0-80 screws on the side of the bracket. Tilt the housing to the side so the bracket will fall away when a soldering iron is touched to the joint. The capacitor may then easily be replaced remote from the housing. Screw the bracket to the housing before soldering.

CAUTION:

Always ground the soldering iron tip when soldering the probe housing to avoid damaging the diodes.

If the Power Sensor failed the tests of (c) or (d), measure the resistance of the diodes CR101 and CR102 with the Model 260 on the 10 kΩ range. The forward resistance of each diode should measure about 500 ohms, and the backward resistance should be greater than 50 kΩ. If the back resistance of a diode measures appreciably less than 50 kΩ, replace it, using the following technique:

NOTE:

Before attempting to replace the diode network in either the -4E or the -5E, C102 and C103 must be removed as described above.

i. While grasping the diode with tweezers, and applying a light upward pull, touch the center post with a small, high-temperature iron. The diode will lift when the solder melts. Now unsolder the far end of the series resistor and lift out the diode-resistor combination (-4A, -4B, -5B, and -4C only).

j. At this point, test the terminating resistors as in (a). If R101 or R102 tests faulty, replace it as follows:

Remove the four 2-56 screws that hold the 100 Ω resistors in place. Unsolder from the center post by pulling the resistor from the rear while heating the center post. (Overheating can cause distortion of the teflon spacer supporting the center conductor.) Replace the new resistor in the reverse order.

k. Replace the diode/resistor networks by soldering the resistor ends first, and then touching the center post as quickly as possible with the iron to solder the diode lead.

4-57. After any critical parts (diodes or terminating resistors) have been replaced, it will be necessary to check the input swr and calibration factor over the frequency range. A swept reflectometer system is recommended for these tests because of the interaction of the adjustments.

CLAMPS: Located on top of the housing and used to vary lead lengths of R101 and R102. Adjust for minimum swr and optimum flatness across the band.

ANGLE: The diodes are normally mounted parallel to the bottom of the channels on top of the housing. Lowering the diodes will improve swr between 8 - 12 GHz.

TAPE: A small strip of copper tape on the diode body will improve rectification efficiency at 18 GHz. Secure with Q MAX or other varnish with a low dielectric constant.

4-58. Calibrate calibration factor using good microwave techniques such as those found in Paragraph 3.2.7 of the 42B instruction manual.

4-59. After repair, if proper adjustment of the Power Sensor is found difficult, return it to the factory. In a covering letter, be sure to include details of all work performed on the Sensor and parts replaced. This information will help our Service Department to return the Sensor to you in the shortest possible time.

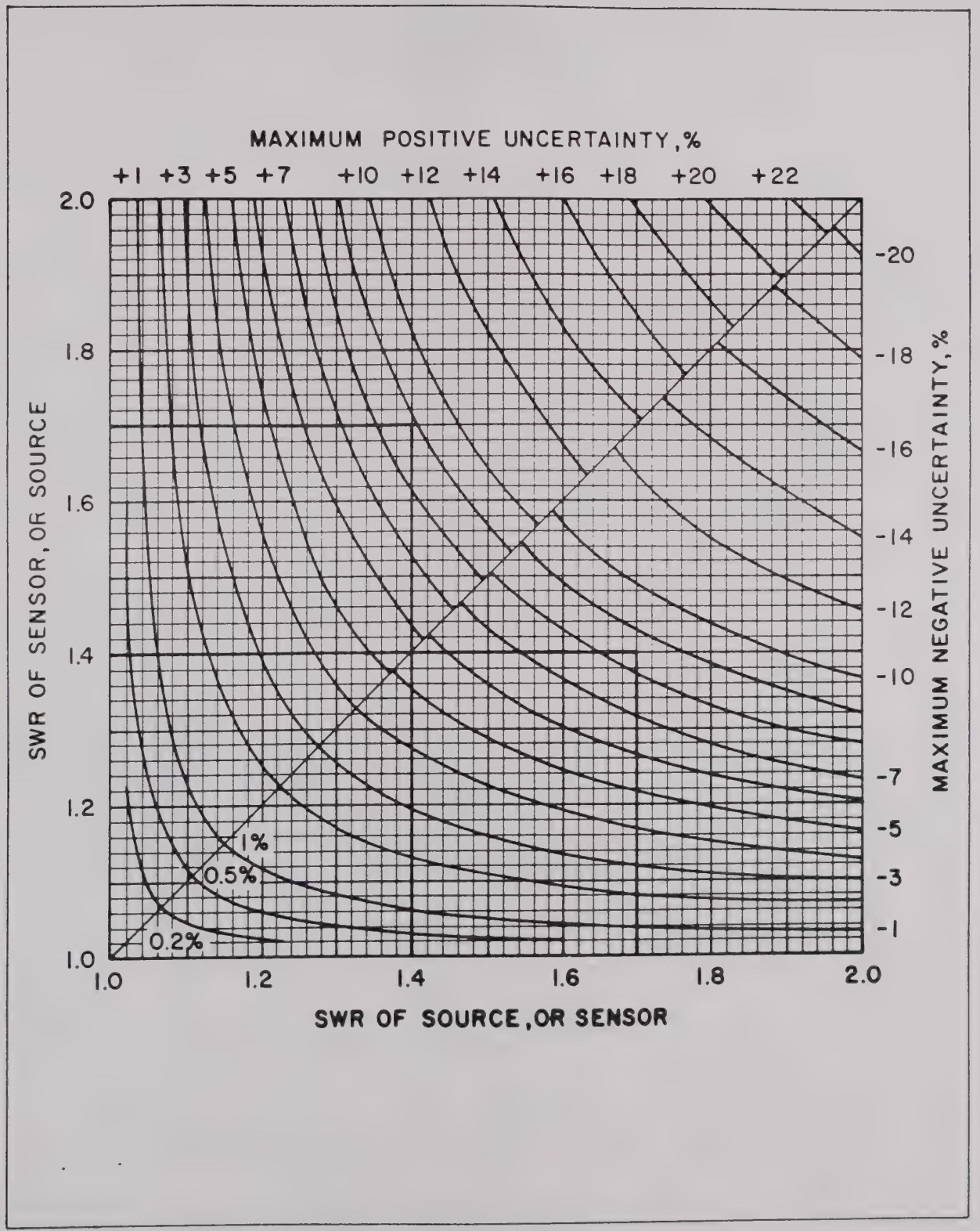


Figure 4-10 Mismatch Uncertainties Chart

SECTION V
PARTS LIST

TABLE OF REPLACEABLE PARTS

Reference		Description		BEC Part No.
FRAME ASSEMBLY (A1)				
J26	Connector		Amphenol 80-PC-2FT (Modified)	479326
S1	Switch, Toggle	3 P.D.T.	CK 7301-S P-Y-Z Q	465223
S2	Switch, Toggle	D.P.D.T.	CK 7203-S-P Y Z-Q	465222
REAR PANEL ASSEMBLY				
F1	Fuse, Slo-Blo	0.3 A 120 V	Buss MDL 3/10	545507
F1	Fuse, Slo-Blo	0.2 A 240 V	Buss MDL 2 10	545508
J20	Receptacle, BNC		Dage 081-1	479123
T1	Transformer, Power		Boonton Electronics	446086
DISPLAY PC BOARD ASSEMBLY				
A1	Op. Amp	CA3140AE	RCA	535050
C1	Capacitor, Cer.	33 pF 5% 1 kV	Sprague C030B102G330J	224139
C2	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C3	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	282217
C4	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C5	Capacitor, Cer.	1000 pF 10% 1 kV	Sprague 10TS-D10	224310
CR1 through CR13	Diode, LED	IT/F-536024	H.P.	536022
IC1	Integrated Circuit	MM74C48N	National Semiconductor	534214
IC2	Integrated Circuit	CD4051BE	RCA	534139
IC3	Integrated Circuit	CD4049AE	RCA	534172
IC4	Resistor Network	100 Ω 2% 1.8 W	AB3168101	345021
IC5	Resistor Network	4.7 kΩ 2% 1.8 W	AB3168472	345020
IC6	Numeric Display	HP5082-7653	H.P.	536809
IC7	Integrated Circuit	DS8863N	National Semiconductor	534215
IC8	Numeric Display	HP5082-7653	H.P.	536809
IC9	Numeric Display	HP5082-7653	H.P.	536809
IC10	Numeric Display	HP5082-7653	H.P.	536809
IC11	Numeric Display	HP5082-7656	H.P.	536810
M1	Meter	OMS-DMA001-CD	Modutec	554332
Q1	Transistor, NPN	2N5088	Motorola	528047
R1	Resistor, MF	93.1 kΩ 1%	RN55	341493
R2	Resistor, Comp.	91 kΩ 5%	AB-EB	343492
R3	Resistor, MF	1.0 MΩ 1%	RN55	341600
R4	Resistor, MF	9.09 kΩ 1%	RN55	341392
R5	Resistor, MF	8.87 kΩ 1%	RN55	341391
R6	Resistor, Comp.	15 kΩ 5%	AB-EB	343417
R7	Resistor, Comp.	4.7 kΩ 5%	AB-EB	343365
R8	Resistor, Var.	10 kΩ 10% 0.5 W	Beckman 72XWR10K	311348
S1 through S26	Switch, Pushbutton	MDP-AU	Schadow	465230
CALIBRATOR ASSEMBLY				
C6	Capacitor, Feedthru	1000 pF	Erie 2499-003 (Modified)	227122
J2	Receptacle, Type N		Amphenol 82-368-1050	479219
S1	Switch, Toggle	S.P.D.T.	Alco MST-105D	465226

Reference		Description		BEC Part No.
CALIBRATOR PC BOARD ASSEMBLY				
A1	Op. Amp.	LM301AN	National Semiconductor	535012
C1	Capacitor, Cer.	470 pF 10% 500 V	RMC-JG	224219
C2	Capacitor, Mica	100 pF 5% 300 V	DM5 FC101J	205006
C3	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C4	Capacitor, Var.	3.5 – 18 pF	Johanson #9373	281011
C5	Capacitor, Cer	1000 pF 10% 1 kV	Sprague 10TS-D10	224310
C6	*See Calibrator Assembly*			
C7	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C8	Capacitor, Cer	0.01 μF 100 V	Erie 805-000X5V0103Z	224119
C9	Capacitor, Mica	36 pF 5% 300 V	DM5-EC360J	205003
C10	Capacitor, Mica	200 pF 5% 100 V	DM5 FA201J	205024
C11	Capacitor, Mica	10 pF 5% 300 V	DM5 CC100J	205002
C12	Capacitor Var	3.5 – 18 pF	Johanson #9373	281011
CR1	Diode, Sil.	HSCH-1001	H.P	530174
CR2	Diode, Sil.	HSCH-1001	H.P	530174
CR3	Diode, Tuning	MV1650	Motorola	530762
IC1	Voltage Reference	AD581JH	Analog Devices	535053
L1	Choke, RF	4.7 μH 10%	Gowanda 10/471	400384
L2	Choke, RF	0.56 μH 10%	Gowanda 10/560	400382
L3	Coil	0.033 μH	Boonton Electronics	400386
Q1	Transistor, NPN	2N3866	Motorola	528116
R1	Resistor, MF	1.5 kΩ 1%	RN55	341317
R2	Resistor, MF	100 kΩ 1%	RN55	341500
R3	Resistor, MF	100 kΩ 1%	RN55	341500
R4	Resistor, Var.	1 kΩ 10% 0.5 W	Bourns 3299X-1-102	311410
R5	Not Used			
R6	Resistor, Comp.	100 kΩ 5%	AB-EB	343500
R7	Resistor, MF	2.43 kΩ 1%	RN55	341337
R8	Resistor, Comp.	1 kΩ 5%	AB-EB	343300
R9	Resistor, Comp.	1 kΩ 5%	AB-EB	343300
R10	Resistor, MF	10.0 kΩ 1%	RN55	341400
R11	Resistor, MF	5.11 kΩ 1%	RN55	341368
R12	Resistor, Comp.	1.2 kΩ 5%	AB-EB	343308
R13	Resistor, Comp.	1.3 kΩ 5%	AB-EB	343311
R14	Resistor, Comp.	75 Ω 5%	AB-EB	343184
R15	Resistor, MF	50.00 Ω 0.1% 0.25 W	PME55-T2	325916
CHOPPER PC BOARD ASSEMBLY (A4)				
C1	Capacitor, PP	0.1 μF 10% 100 V	F-Dyne PP11-1-100-10	234148
C2	Capacitor, PP	0.1 μF 10% 100 V	F-Dyne PP11-1-100-10	234148
IC1	Integrated Circuit	CD4016BE (Selected)	RCA	534223
R1	Resistor, MF	5.62 MΩ 1% 0.25 W	GE-12	325397
R2	Resistor, MF	5.62 MΩ 1% 0.25 W	GE-12	325397
R3	Resistor MF	51.1 kΩ 1%	RN55	341468
R4	Resistor, Var.	20 kΩ 10% 0.5 W	Beckman 72PR20K	311354
R5	Resistor, Var.	20 kΩ 10% 0.5 W	Beckman 72PR20K	311354
R6	Resistor, MF	51.1 kΩ 1%	RN55	341468
CONTROL PC BOARD ASSEMBLY (A5)				
BT1	Power Cell	400 5S	Power Conversions Inc.	556005
BT2	Power Cell	400 5S	Power Conversions Inc	556005
C1	Capacitor, Mica	430 pF 1% 500 V	DM15-431F	200037

TABLE OF REPLACEABLE PARTS (cont)

Reference		Description		BEC Part No.
CONTROL PC BOARD ASSEMBLY (A5) (Cont.)				
C2	Capacitor, Mica	100 pF 5% 500 V	DM15 F101J	200001
C3	Capacitor, Tant.	0.47 μF 10% 35 V	Sprague 196D474X9035HA1	283324
C4 through C7	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
CR1	Diode, Sig.	1N914	T.I.	530058
CR2	Diode, LED	IT/F 536024	H P	536023
IC1	Integrated Circuit	SN7404N	T.I.	534042
IC2	Resistor Network	4.7 kΩ 2% 1.8 W	AB3168472	345020
IC3	Integrated Circuit	Z80-CPU-PS	Zilog	534159
IC4	Integrated Circuit	SN74LS42N	T.I.	534210
IC5	Integrated Circuit	SN74LS08N	T I	534156
IC6	PROM	Programmed	4200-1	534221
IC7	PROM	Programmed	4200-1	534222
IC8	Integrated Circuit	P2114	Intel	534212
IC9	Integrated Circuit	CD4011AE	RCA	534022
IC10	Integrated Circuit	P2114	Intel	534212
IC11	Integrated Circuit	HM3-6501-9	Harris Semiconductor	534213
IC12	Integrated Circuit	HM3-6501-9	Harris Semiconductor	534213
IC13	Resistor Network	4.7 kΩ 2% 1.8 W	AB3168472	345020
IC14	Integrated Circuit	SN74LS42N	T.I.	534210
IC15	Integrated Circuit	SN74LS32N	T.I.	534168
IC16	Integrated Circuit	AM8255 APC	Advanced Micro Devices	534171
IC17	Resistor Network	4.7 kΩ 2% 1.8 W	AB3168472	345020
IC18	Integrated Circuit	P8279	Intel	534211
L1	Choke, RF	15 μH 10%	Gowanda 10/152	400373
Q1	Transistor, NPN	2N3904	Motorola	528071
R1	Resistor, Comp.	330 Ω 5%	AB-EB	343250
R2	Resistor, Comp.	10 kΩ 5%	AB-EB	343400
R3	Resistor, Comp.	10 kΩ 5%	AB-EB	343400
R4	Resistor, Comp.	4.7 kΩ 5%	AB-EB	343365
R5	Resistor, Comp.	5.1 kΩ 5%	AB-EB	343368
R6	Resistor, MF	100 Ω 1%	RN55	341200
R7	Resistor, Comp.	10 kΩ 5%	AB-EB	343400
S1	Switch, Rocker	(8) SPST	Grayhill 76SB08	465225
INPUT PC BOARD ASSEMBLY (A6)				
A1	Op. Amp.	LM301AN	National Semiconductor	535012
A2	Op. Amp.	LM311N	National Semiconductor	535034
A3	Op. Amp.	LM301AN	National Semiconductor	535012
A4	Op. Amp.	CA3140AE	RCA	535050
A5	Op. Amp.	IT/F 535052	Boonton	535062
A6	Op Amp.	IT/F 535052	Boonton	535062
A7	Op. Amp.	IT/F 535052	Boonton	535079
A8	Op Amp.	CA3140AE	RCA	535050
A9	Op. Amp.	CA3140AE	RCA	535050
C1	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC-Q33	224139
C2	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C3	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC-Q33	224139
C4	Capacitor, PE	0.01 μF 10% 80 V	Sprague 192P1039R8	234092
C5	Capacitor, Cer.	150 pF 10% 1 kV	Sprague 10TS-T15	224314
C6	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC-Q33	224139
C7	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC-Q33	224139
C8	Capacitor, Cer.	1000 pF 10% 1 kV	Sprague 10TS-D10	224310
C9	Capacitor, Mica	1500 pF 1% 500 V	Cornell Dubilier CD19FD152F-03	200531
C10	Not Used			
C11	Not Used			
C12	Capacitor, Cer.	0.01 μF 100 V	Erie 805-000X5V0103Z	224119
C13	Capacitor, Cer.	68 pF 10% 1 kV	Sprague 10TS-Q68	224312
C14	Capacitor, PE	0.01 μF 10% 80 V	Sprague 192P1039R8	234092
C15	Capacitor, Cer.	0.01 μF 100 V	Erie 805-000X5V0103Z	224119
C16	Capacitor, Cer.	68 pF 10% 1 kV	Sprague 10TS-Q68	224312
C17	Capacitor, Cer.	2200 pF 10% 250 V	Sprague 2SS-D22	224309
C18	Capacitor, PE	0.01 μF 10% 80 V	Sprague 192P1039R8	234092
C19	Capacitor, Cer.	330 pF 10% 1 kV	Sprague 10TS-T33	224313
C20	Capacitor, PP	0.1 μF 10% 100 V	F-Dyne PP11-.1-100-10	234148

Reference		Description		BEC Part No.
C21	Not Used			
C22	Capacitor, PP	0.1 μF 10% 100 V	F Dyne PP11 .1-100-10	234148
C23	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC Q33	224139
C24	Not Used			
C25	Capacitor, Cer.	33 pF 5% 1 kV	Sprague 10TCC-Q33	224139
C26	Capacitor, Cer.	1000 pF 10% 1 kV	Sprague 10TS-D10	224310
C27 through C34	Capacitor, Tant.	6.8 μF 10% 35 V	Sprague 196D685X9035KA1	283217
C35	Capacitor, Cer.	150 pF 10% 1 kV	Sprague 10TS-T15	224314
C36	Capacitor, EL	100μF 20% 25V	United Chemcon SM-25-VB-100-M	283334
IC1	Integrated Circuit	AM8255 APC	Advanced Micro Devices	534171
IC2	Op. Amp.	AD565JN/BIN	Analog Devices	421034
IC3	Integrated Circuit	CD4053BE	RCA	534207
IC4	Not Used			
IC5	Integrated Circuit	CD4047AE	RCA (Only)	534229
IC6	Integrated Circuit	CD4051BE	RCA (Only)	534209
IC7	Integrated Circuit	CD4013BE	RCA (Only)	534205
IC8	Integrated Circuit	CD4013BE	RCA (Only)	534205
IC9	Integrated Circuit	CD4016BE	RCA (Only)	534218
IC10	Integrated Circuit	CD4016BE	RCA (Only)	534218
IC11	Integrated Circuit	CD4075BE	RCA	534206
IC12	Resistor Network	47 kΩ 2% 1.6 W	AB3148473	345019
IC13	Integrated Circuit	CD4051BE	RCA (Only)	534209
IC14	Integrated Circuit	CD4051BE	RCA (Only)	534209
R1	Resistor, Var.	100 Ω 10% 0.5 W	Beckman 72PR100	311408
R2	Resistor, Comp	2.7 kΩ 5%	AB-EB	343341
R3	Resistor, Comp.	1 kΩ 5%	AB EB	343300
R4	Resistor, Comp.	100 Ω 5%	AB-EB	343200
R5	Resistor, MF	10.0 kΩ 1%	RN55	341400
R6	Resistor, MF	5.11 kΩ 1%	RN55	341368
R7	Resistor, MF	9.09 kΩ 1%	RN55	341392
R8	Resistor, MF	1.0 kΩ 1%	RN55	341300
R9	Resistor, MF	10.0 kΩ 1%	RN55	341400
R10	Resistor, Comp.	3 MΩ 5%	AB-EB	343646
R11	Resistor, Var.	50 kΩ 10% 0.5 W	Beckman 72PR50K	311393
R12	Resistor, MF	1.0 MΩ 1%	RN55	341600
R13	Resistor, MF	1.0 MΩ 1%	RN55	341600
R14	Resistor, MF	237 kΩ 1%	RN55	341536
R15	Resistor, MF	249 kΩ 1%	RN55	341538
R16	Resistor, MF	12.1 kΩ 1%	RN55	341408
R17	Resistor, MF	806 kΩ 1%	RN55	341587
R18	Resistor, Comp.	12 MΩ 5%	AB-EB	343708
R19	Resistor, Comp.	12 MΩ 5%	AB-EB	343708
R20	Resistor, MF	1.82 kΩ 1%	RN55	341325
R21	Resistor, MF	20.0 kΩ 1%	RN55	341429
R22	Resistor, MF	221 kΩ 1%	RN55	341533
R23	Resistor, MF	1.0 MΩ 1%	RN55	341600
R24	Not Used			
R25	Resistor, MF	1.0 MΩ 1%	RN55	341600
R26 through R28	Resistor, MF	100.0 kΩ 1%	RN55	341500
R29	Resistor, MF	110 kΩ 1%	RN55	341504
R30	Resistor, MF	100.0 kΩ 1%	RN55	341500
R31	Resistor, MF	110 kΩ 1%	RN55	341504
R32	Resistor, MF	9.09 kΩ 1%	RN55	341392
R33	Resistor, MF	9.09 kΩ 1%	RN55	341392
R34	Resistor, Comp	10 kΩ 5%	AB-EB	343400
R35	Resistor, Comp.	5.1 kΩ 5%	AB-EB	341368
R36	Resistor, Var.	10 kΩ 10% 0.5 W	Beckman 72PR10K	311328
R37	Resistor, Comp	3.9 kΩ 5%	AB-EB	343357
R38	Resistor, MF	7.87 kΩ 1%	RN55	341386
R39	Resistor, MF	80.6 kΩ 1%	RN55	341487
R40	Resistor, MF	806 kΩ 1%	RN55	341587
R41	Not Used			
R42	Resistor, Comp.	7.5 kΩ 5%	AB-EB	343384
R43	Not Used			
R44	Resistor, Var.	200 kΩ 10% 0.5 W	Beckman 72PR200K	311401
R45	Resistor, Var.	10 kΩ 10% 0.5 W	Beckman 72PR10K	311328
R46	Not Used			
R47	Resistor, Comp.	3.9 kΩ 5%	AB-EB	343357
R48	Resistor, MF	909 kΩ 1%	RN55	341592
RT1	Thermistor	50 Ω 10%	Fenwal LB15J1	325007

TABLE OF REPLACEABLE PARTS (cont)

Reference	Description			BEC Part No.
POWER SUPPLY PC BOARD				
A1	Op. Amp.	LM339N	National Semiconductor	535018
C1	Capacitor, Elec.	800 µF +75/-10% 50 V Mallory	CG801U050R2C3PH	283347
C2	Capacitor, Elec.	800 µF +75/-10% 50 V Mallory	CG801U050R2C3PH	283347
C3	Capacitor, Elec.	4500 µF +75/-10% 25 V	GE 86F537M	283318
C4	Capacitor, Elec.	10 µF 20% 25 V	United Chemicon SM-25VB-10M	283336
C5	Capacitor, Elec.	100 µF 20% 16 V	United Chemicon SM-16VB-100M	283337
C6	Capacitor, Elec.	100 µF 20% 16 V	United Chemicon SM-16VB-100M	283337
C7	Capacitor, Elec.	1000 µF +50/-10% 10 V	Sprague 503D108F010PE	283329
C8	Capacitor, Cer.	3300 pF 10% 100 V	Kemet C052C332K1X5CA	224296
C9	Capacitor, Elec.	100 µF 20% 16 V	United Chemicon SM-16VB-100M	283337
CR1	Diode, Bridge	KPB-02	General Inst.	532013
CR2	Diode, Bridge	VS-248	Varo	532014
CR3 through CR6	Diode, Sil	IN4001	Motorola	530151
IC1	Voltage Regulator	µA7805UC	Fairchild	535011
IC2	Voltage Regulator	µA78MGUIC (Modified)	Fairchild	535058
IC3	Voltage Regulator	µA79MGUIC (Modified)	Fairchild	535087
IC4	Voltage Regulator	µA78GUIC (Modified)	Fairchild	535059
IC5	Voltage Regulator	µA79MGUIC (Modified)	Fairchild	535087
IC6	Integrated Circuit	CD4013BE	RCA	534205
P1	Conn. Header	5 Pin	Panduit HPSS156-5-C	477345
P4	Conn. Header	6 Pin	Molex 22-04-2061	477327
P5	Conn. Header	6 Pin	Molex 22-04-2061	477327
P7 through P10	Conn. Header	6 Pin	Molex 22-04-2061	477327
R1	Resistor, MF	10.0 kΩ 1%	RN55	341400
R2	Resistor, MF	4.99 kΩ 1%	RN55	341367
R3	Resistor, MF	2.21 kΩ 1%	RN55	341333
R4	Resistor, MF	12.7 kΩ 1%	RN55	341410
R5	Resistor, Var.	500 Ω 10% 0.5 W	Beckman 72PR500	311305
R6 through R8	Resistor, MF	4.99 kΩ 1%	RN55	341367
R9	Resistor, Comp.	1 kΩ 5%	AB-EB	343300
R10	Resistor, MF	453 Ω 1%	RN55	341263
R11	Resistor, Var.	100 Ω 10% 0.5 W	Beckman 72PR100	311408
R12	Resistor, MF	464 Ω 1%	RN55	341264
R13	Resistor, Comp.	100 kΩ 5%	AB-EB	343500
R14	Resistor, Comp.	330 Ω 5% 1 W	AB-GB	302087
R15	Resistor, Comp.	5.1 kΩ 5%	AB-EB	343368

Reference	Description			BEC Part No.
POWER SUPPLY PC BOARD				
R16	Resistor, MF	2.21 kΩ 1%	RN55	341333
R17	Resistor, MF	2.80 kΩ 1%	RN55	341343
R18	Resistor, Comp.	5.1 kΩ 5%	AB-EB	343368
R19	Resistor, Comp.	51 kΩ 5%	AB-EB	343468
MISCELLANEOUS				
	Cable Assembly (P.S. to Display)			571142
	Cable Assembly (P.S. to Input)			571143
	Cable Assembly (P.S. to Control 1)			571144
	Cable Assembly (P.S. to Control 2)			571145
	Cable Assembly (P.S. to Interface) (Option -01)			571147
	Cable Assembly (P.S. to Input) (Option -03)			571148
	Cable Assembly (Control to Display)			920046
	Cable Assembly (Control to Input)			920050
INTERFACE PC BOARD ASSEMBLY (-01 OPTION)				
C1	Capacitor, Tant.	10 µF 20% 25 V	Sprague 196D106X0025KM1	283293
C2	Capacitor, Tant.	10 µF 20% 25 V	Sprague 196D106X0025KM1	283293
IC1	PROM	Programmed 4200-1	Boonton Electronics	534226
IC2	Resistor Network	3 k 2% 2 W	Beckman 784-1-R3K	534017
IC3	Integrated Circuit	AM8255 APC	Advanced Micro Devices	534171
IC4	Integrated Circuit	SN74LS00N	T.I.	534167
IC5	Integrated Circuit	SN74LS04N	T.I.	534155
IC6	Integrated Circuit	SN7402N	T.I.	534027
IC7	Integrated Circuit	SN74LS74N	T.I.	534157
IC8	Integrated Circuit	N8T26AN	Signetics	534097
IC9	Integrated Circuit	N8T26AN	Signetics	534097
IC10	Integrated Circuit	SN7438N	T.I.	534108
INTERFACE PC BOARD ASSEMBLY (-01 OPTION) (Cont.)				
IC11	Resistor Network	3 kΩ/6.2 kΩ 5% 2 W	National Semiconductor RA28-3K/6.2KN	345016
IC12	Resistor Network	3 kΩ/6.2 kΩ 5% 2 W	National Semiconductor RA28-3K/6.2KN	345016
J1	Connector	24 Pin	Amp 552230-1	479350
S1	Switch, Slide	7 Sw. Sections	CTS-206-7	465215
MISCELLANEOUS, (-01 OPTION)				
	Cable Assembly	(Input 1, Input 2, Control	Boonton Electronics	920052
	Cable Assembly	1 M Long, HP 10631	HP-IB	571133
SECOND INPUT CHANNEL (-03 OPTION)				
	(See Input PC Board Assembly Parts List)			
CHOPPER PC BOARD ASSEMBLY (-03 OPTION)				
	(See Chopper PC Board Assembly Parts List)			
MISCELLANEOUS, (-03 OPTION)				
	Cable Assembly	(Input 1, Input 2, Control, & Interface)	Boonton Electronics	920052
	Connector		Amphenol 80-PC-2FT (modified)	479326

SECTION VI
SCHEMATIC DIAGRAMS

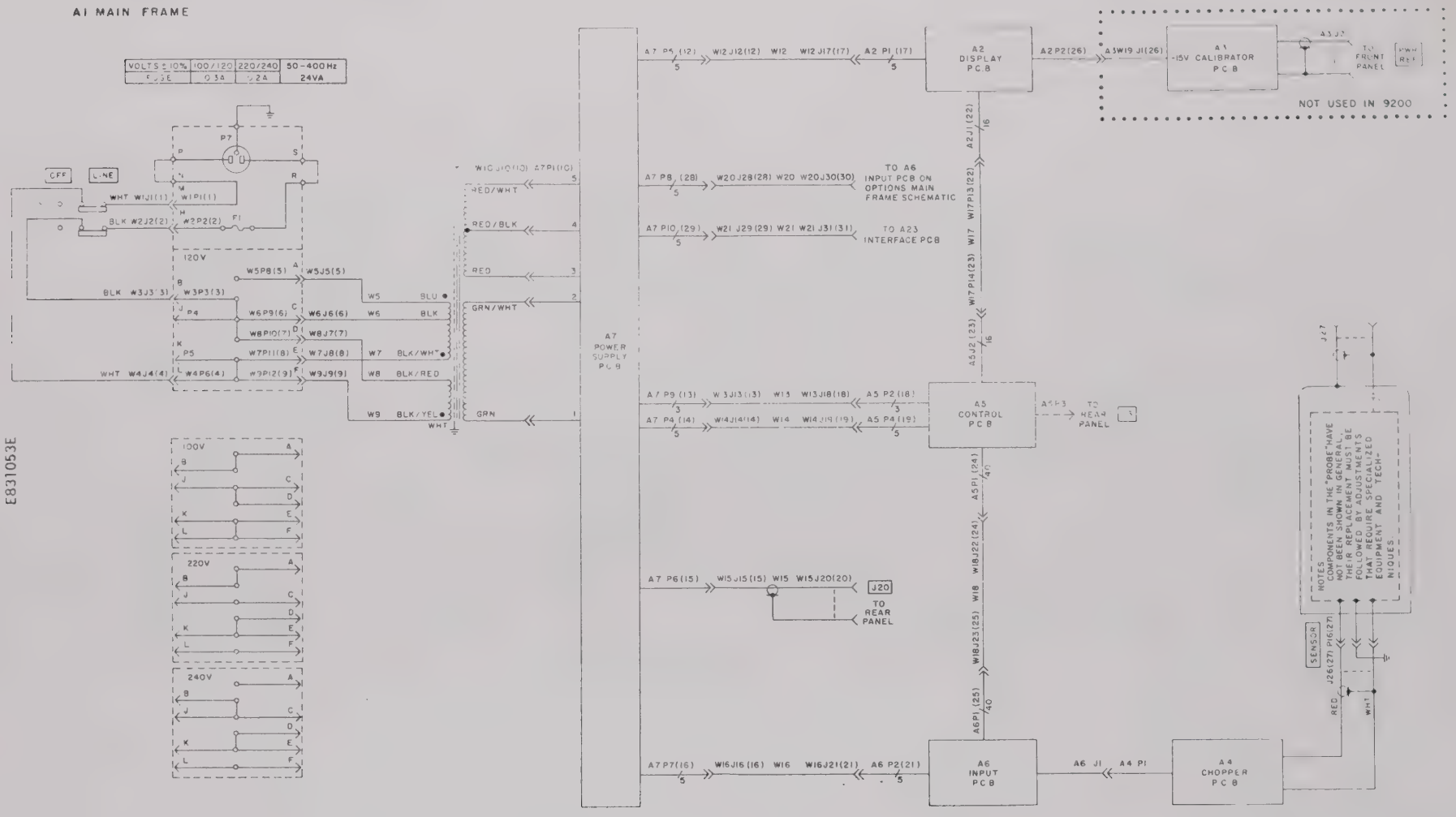


Figure 6-1 Main Frame A1, Schematic Diagram

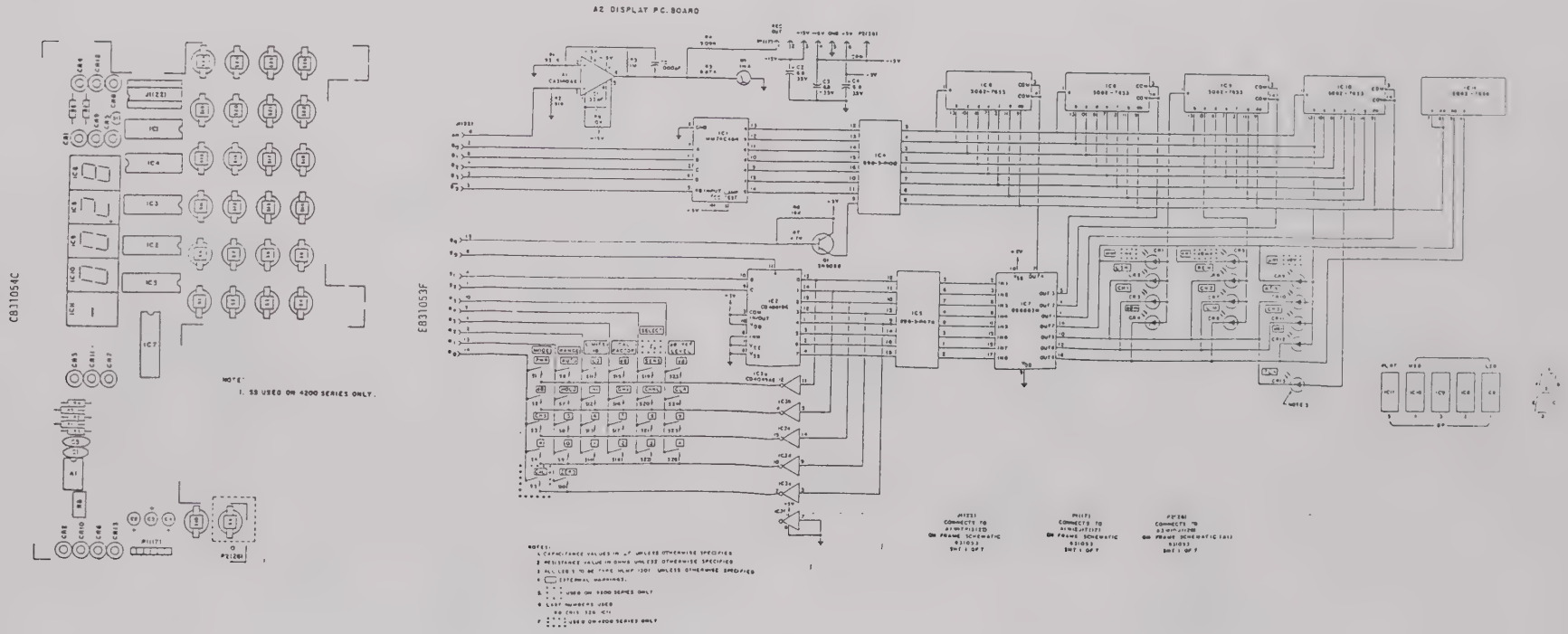
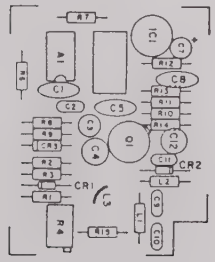
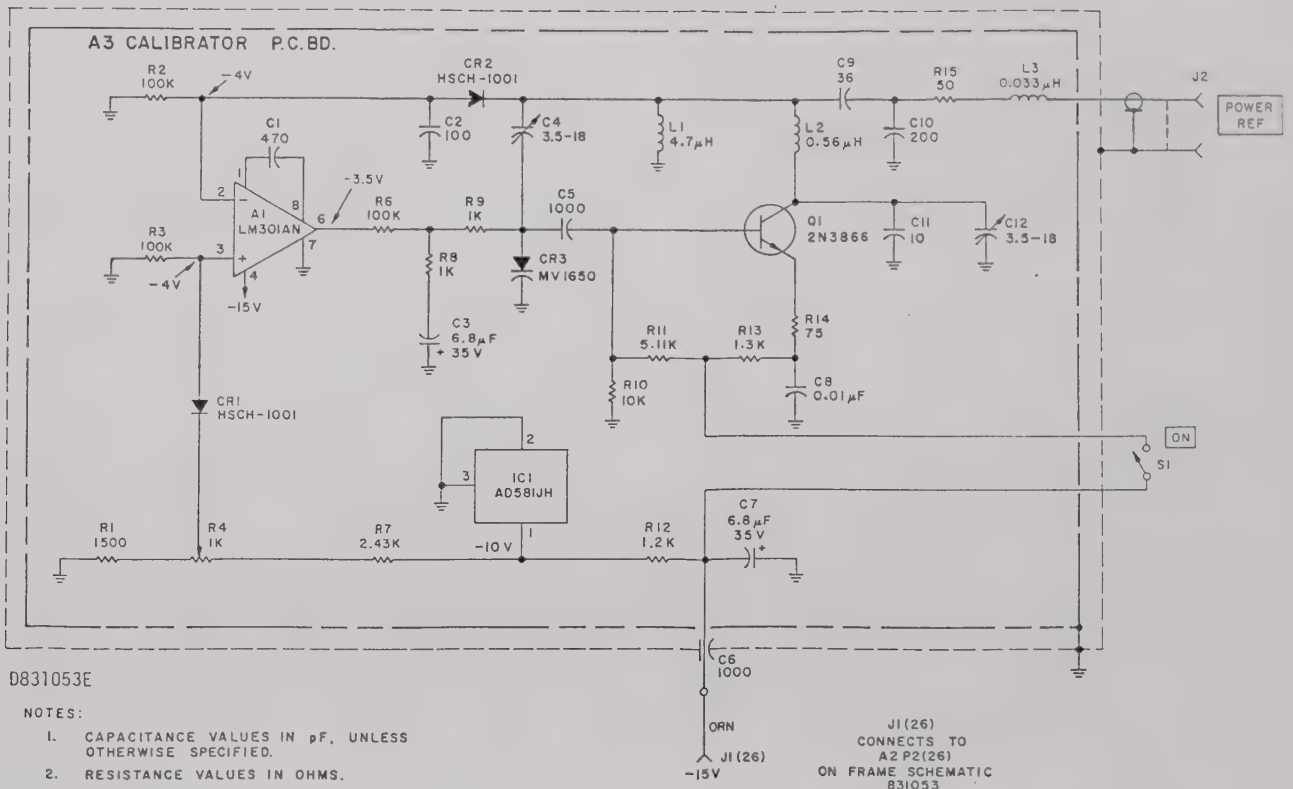


Figure 6-2 Display Board A2, Schematic Diagram

B831044C



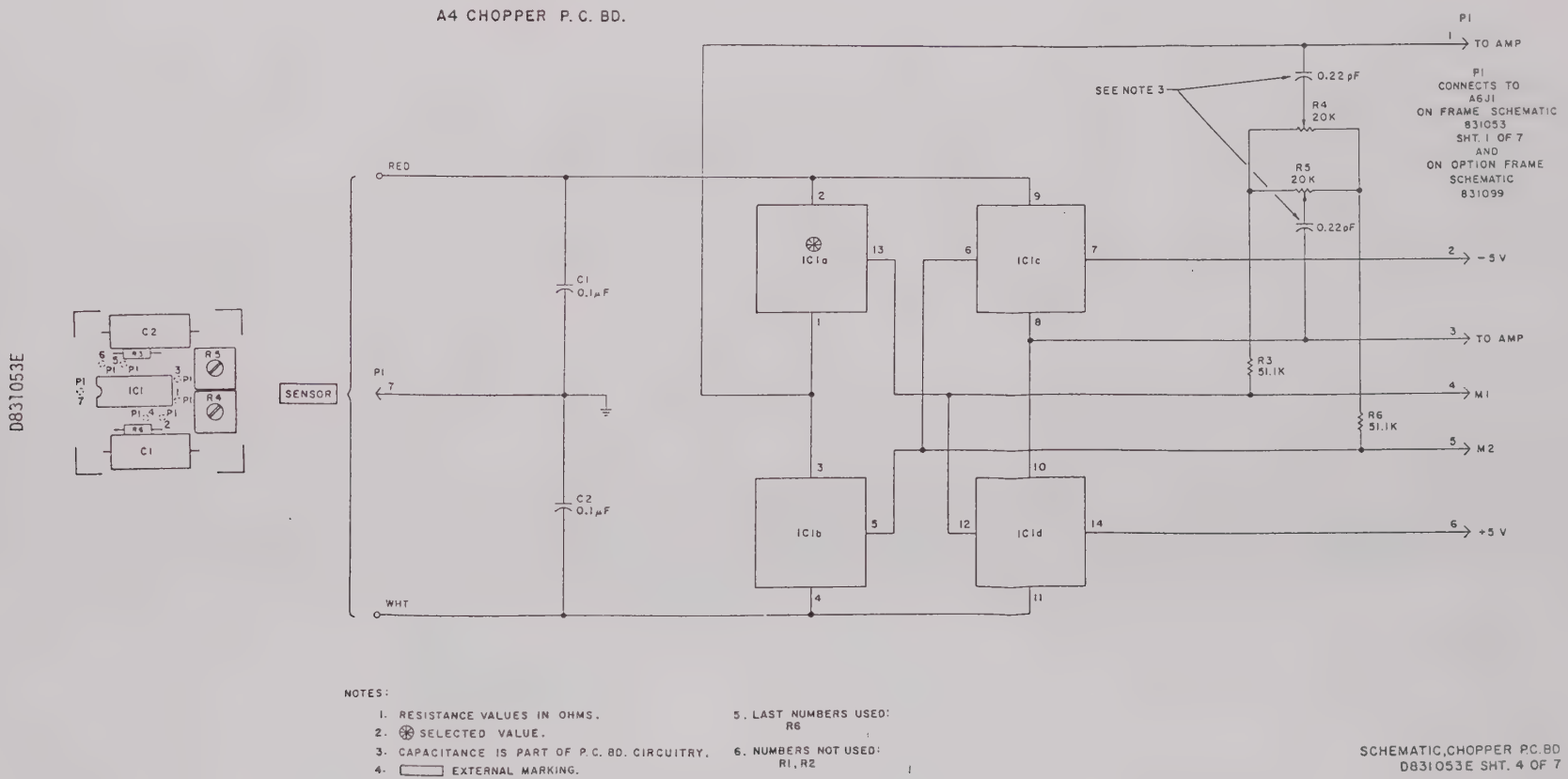


D831053E

NOTES:

1. CAPACITANCE VALUES IN pF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3. [ ] EXTERNAL MARKINGS.
4. LAST NUMBERS USED:
   C12 R15
5. NUMBERS NOT USED:
   R5

Figure 6-3 Power Reference Board A3, Schematic Diagram



NOTES:

1. RESISTANCE VALUES IN OHMS.
2. ⊛ SELECTED VALUE.
3. CAPACITANCE IS PART OF P.C. BD. CIRCUITRY.
4. ▭ EXTERNAL MARKING.
5. LAST NUMBERS USED: R6
6. NUMBERS NOT USED: R1, R2

SCHEMATIC, CHOPPER P.C. BD
D831053E SHT. 4 OF 7

Figure 6-4 Chopper Board A4, Schematic Diagram

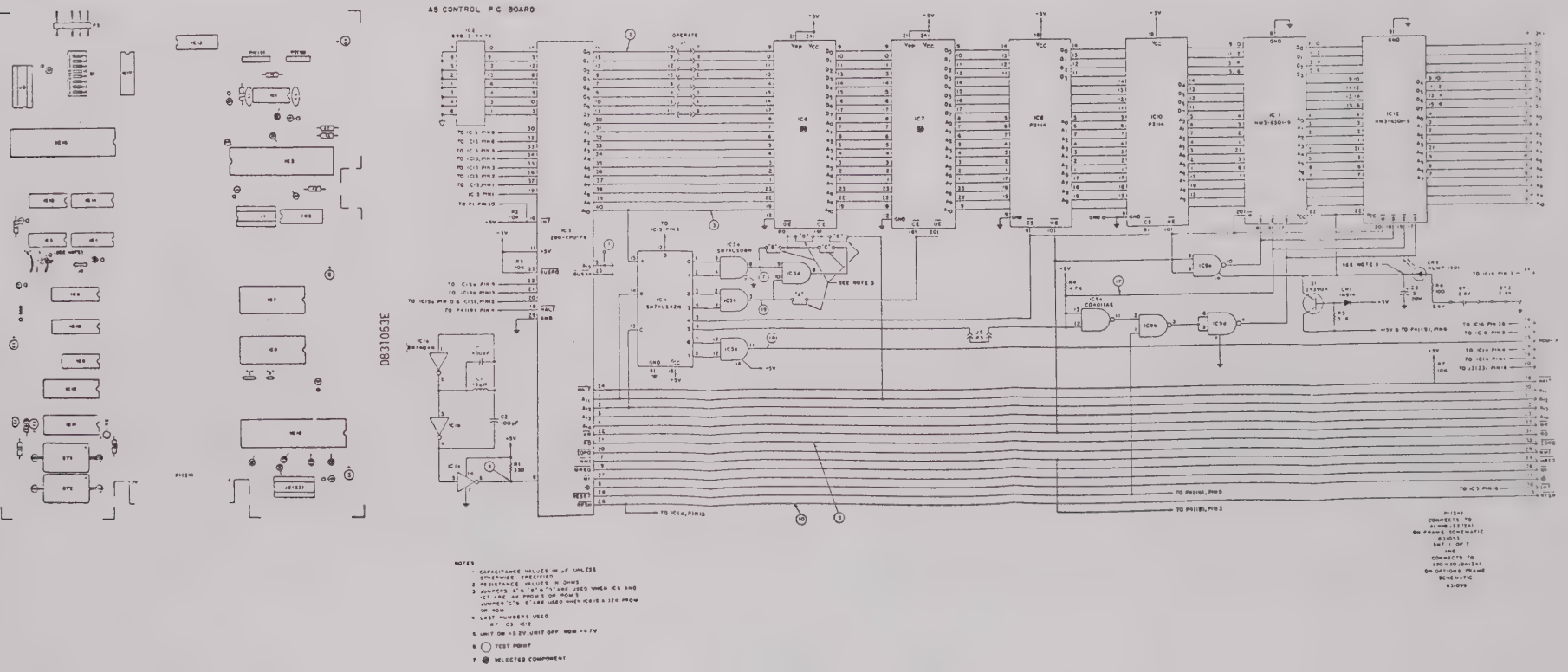

A5 CONTROL P C BOARD
D831053E
OPERATE
NOTES
1 CAPACITANCE VALUES IN µF UNLESS OTHERWISE SPECIFIED
2 RESISTANCE VALUES IN OHMS
3 JUMPERS A"& B" & D" ARE USED WHEN IC6 AND IC7 ARE 4K PROMS OR ROM S
JUMPER "C" & E" ARE USED WHEN IC6 IS A 2K PROM OR ROM
4 LAST NUMBERS USED BY IC3 IC12
5 UNIT ON = 3.2V, UNIT OFF HIGH = 0.7V
6 TEST POINT
7 SELECTED COMPONENT

Figure 6-5 Control Board A5, Schematic Diagram (Sheet 1 of 2)

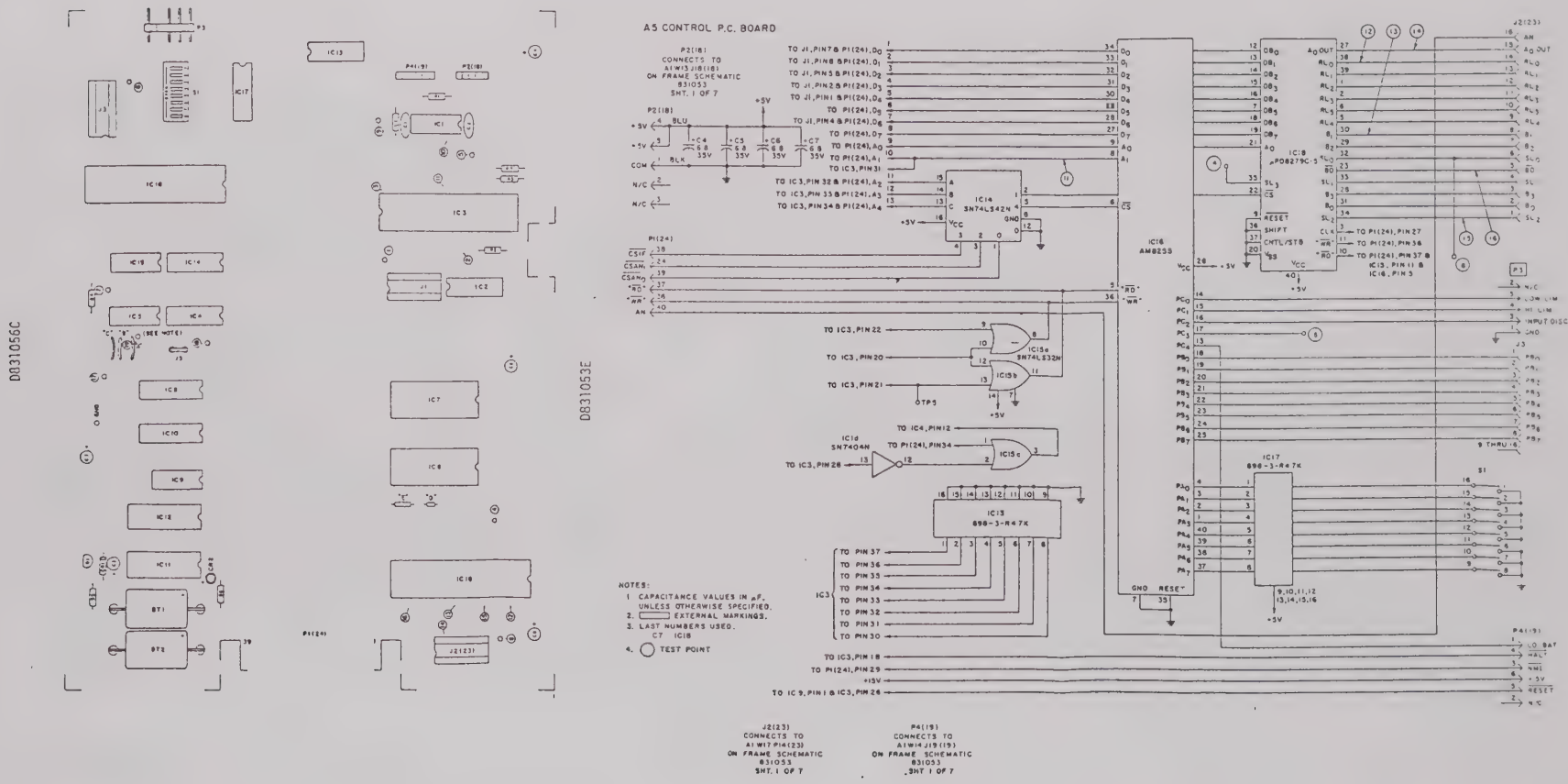

D031056C
D031053E
A5 CONTROL P.C. BOARD
NOTES:
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. EXTERNAL MARKINGS.
3. LAST NUMBERS USED. C7 IC18
4. TEST POINT
J2(23) CONNECTS TO A1W17 P14(23) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P4(19) CONNECTS TO A1W14 J19(19) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7

Figure 6-5 Control Board A5,
Schematic Diagram (Sheet 2 of 2)

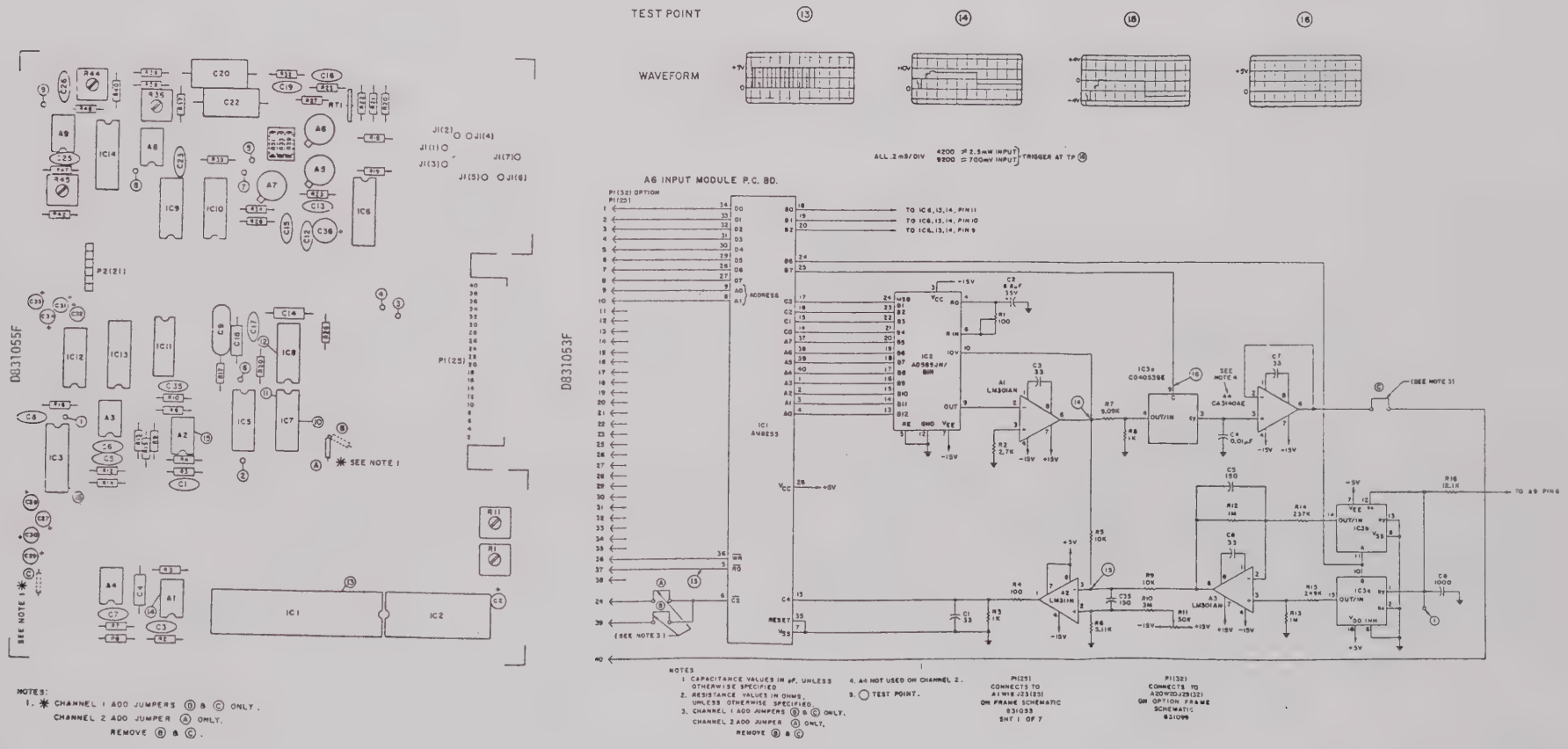
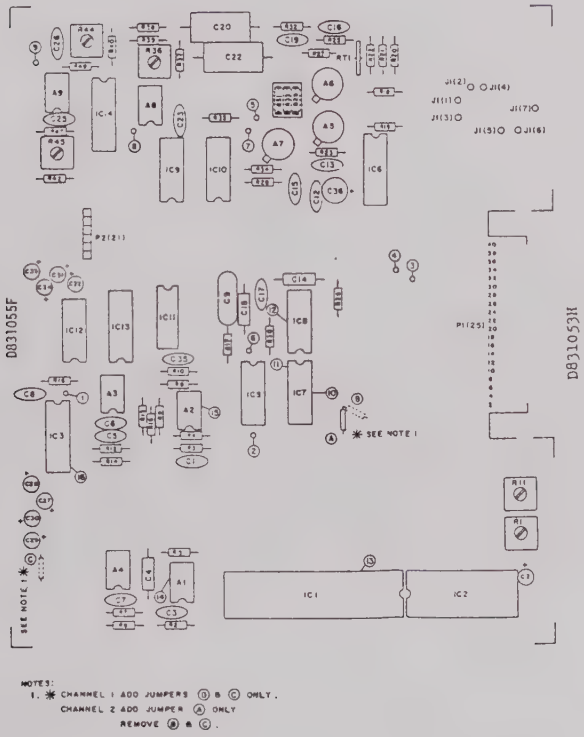

D831055F
D831053F
TEST POINT
WAVEFORM
A6 INPUT MODULE P.C. BD.
SEE NOTE 1
NOTES:
1. ✱ CHANNEL 1 ADD JUMPERS (B) & (C) ONLY.
CHANNEL 2 ADD JUMPER (A) ONLY.
REMOVE (B) & (C).
NOTES
1. CAPACITANCE VALUES IN pF. UNLESS OTHERWISE SPECIFIED
2. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
3. CHANNEL 1 ADD JUMPERS (B) & (C) ONLY.
CHANNEL 2 ADD JUMPER (A) ONLY.
REMOVE (B) & (C).
4. A6 NOT USED ON CHANNEL 2.
5. ◯ TEST POINT.
P1(25) CONNECTS TO A1W19 J25(25) ON FRAME SCHEMATIC 831033 SHT 1 OF 7
P1(32) CONNECTS TO A20W20-J29(32) ON OPTION FRAME SCHEMATIC 831099

Figure 6-6 Input Module Board A6, Schematic Diagram (Sheet 1 of 2)



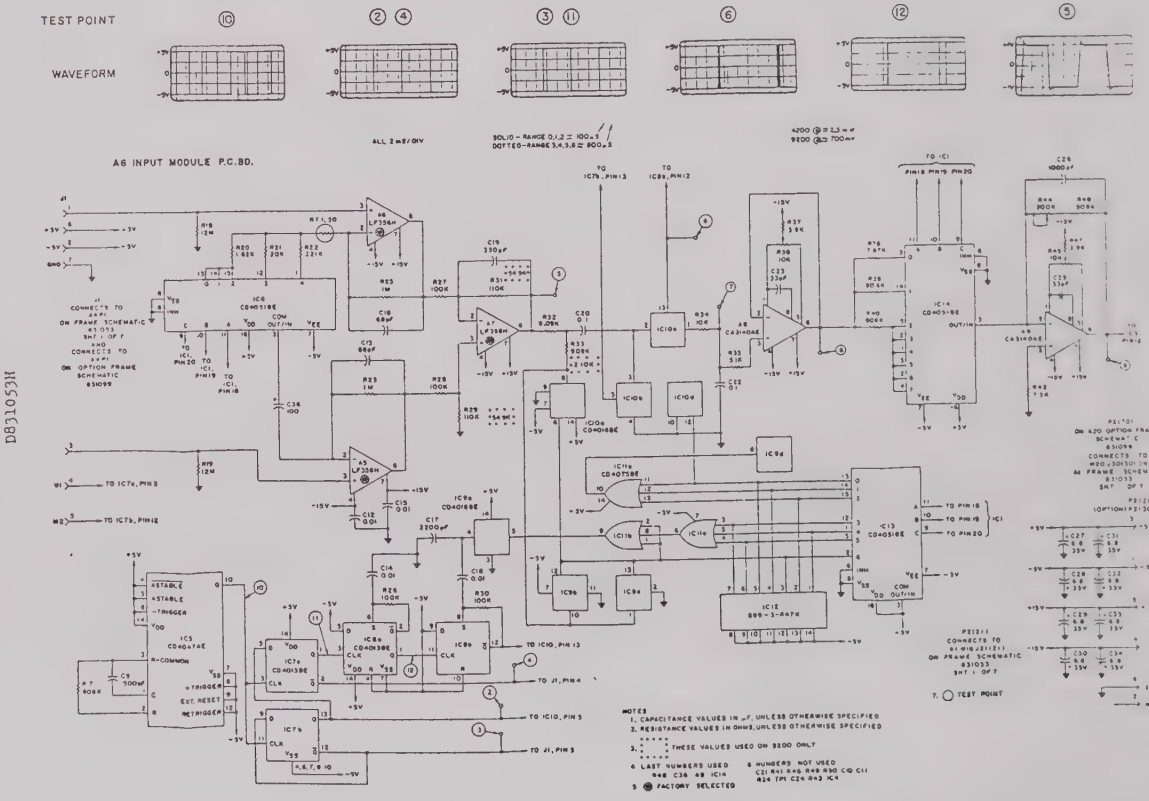
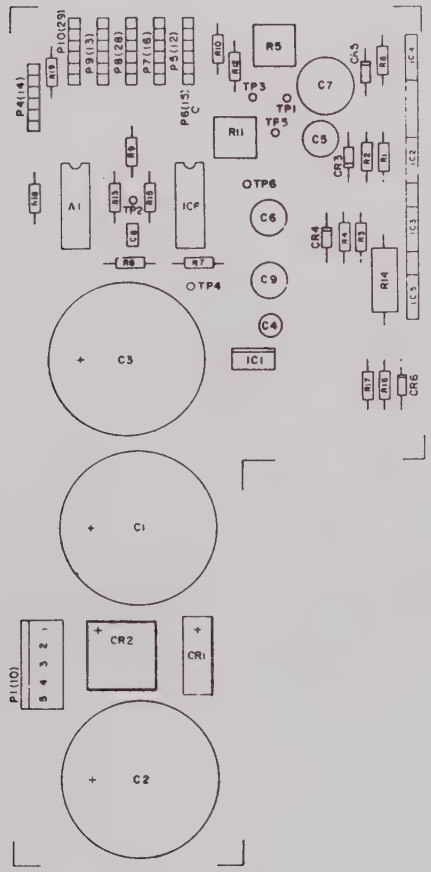
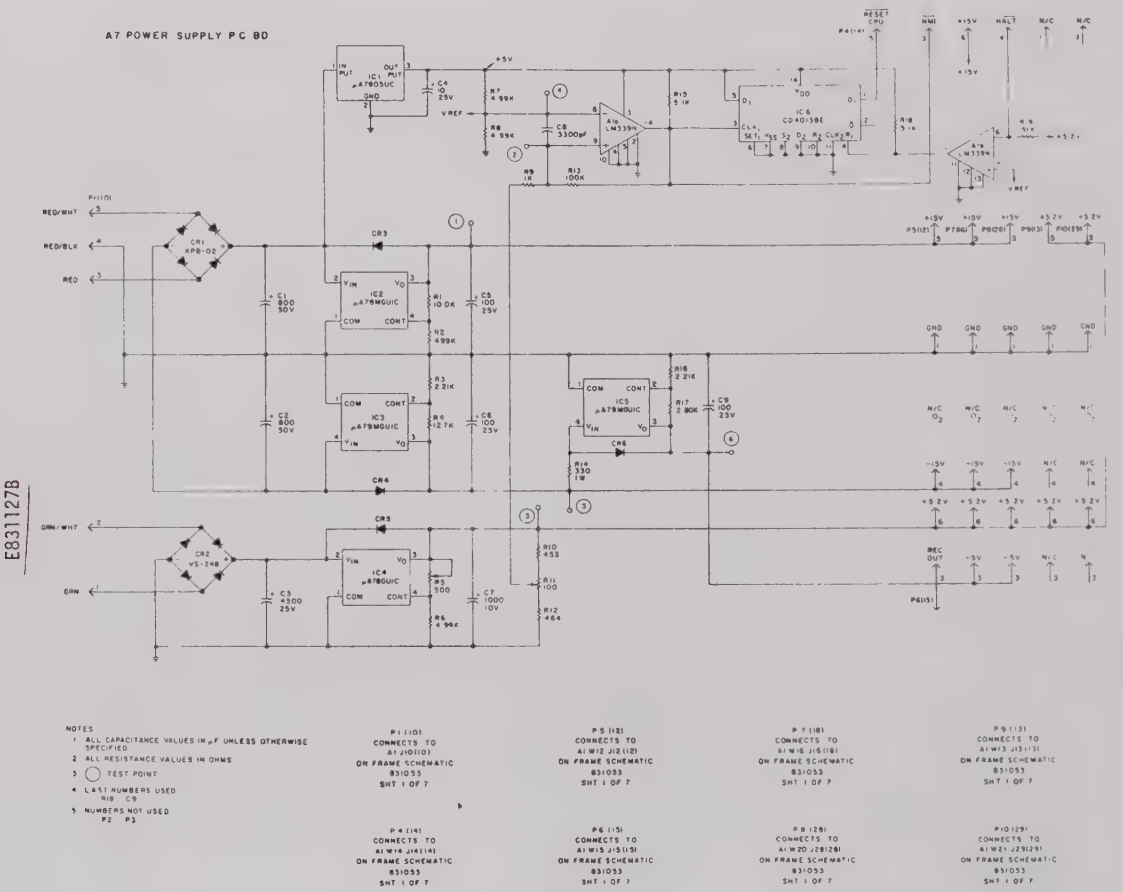

TEST POINT
WAVEFORM
A6 INPUT MODULE P.C.BD.
D031053H
NOTES
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED
2. RESISTANCE VALUES IN OHMS, UNLESS OTHERWISE SPECIFIED
3. ✱ THESE VALUES USED ON 9200 ONLY
4. LAST NUMBERS USED
5. FACTORY SELECTED
6. NUMBERS NOT USED

Figure 6-6 Input Module Board A6,
Schematic Diagram (Sheet 2 of 2)

C831166B



E831127B



NOTES
1. ALL CAPACITANCE VALUES IN μF UNLESS OTHERWISE SPECIFIED
2. ALL RESISTANCE VALUES IN OHMS
3. ◯ TEST POINT
4. LAST NUMBERS USED R18 C6
5. NUMBERS NOT USED P2 P3

P1 (10) CONNECTS TO A1 J101(10) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P5 (12) CONNECTS TO A1 W12 J12(12) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P7 (16) CONNECTS TO A1 W16 J16(16) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P9 (3) CONNECTS TO A1 W3 J13(13) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P4 (14) CONNECTS TO A1 W14 J14(14) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P6 (15) CONNECTS TO A1 W15 J15(15) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P8 (28) CONNECTS TO A1 W20 J28(28) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P10 (29) CONNECTS TO A1 W21 J29(29) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

Figure 6-7 Power Supply Board A7, Schematic Diagram

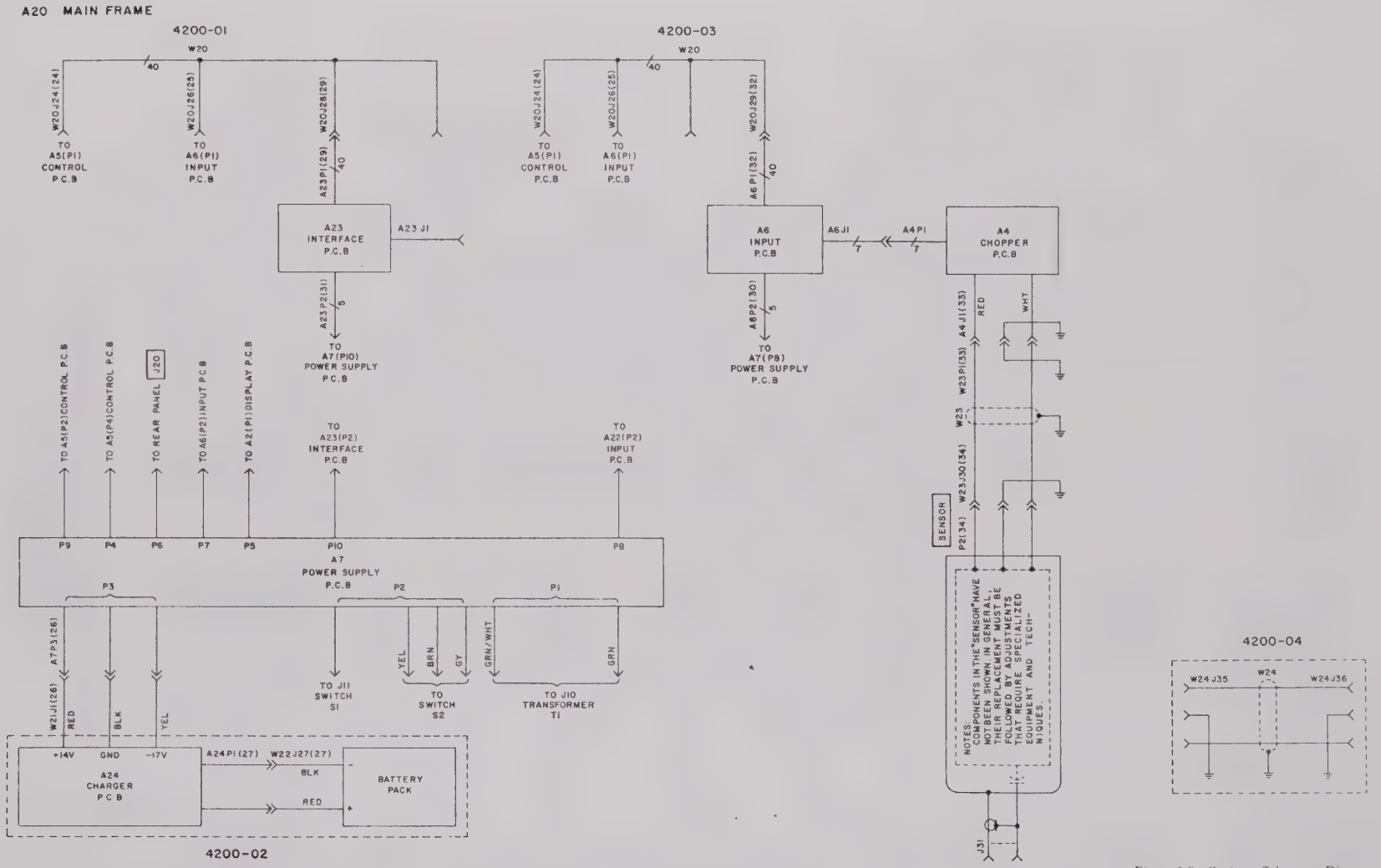


Figure 6-8 Options, Schematic Diagram

ADDENDUM
SWITCHING POWER SUPPLY

1. GENERAL.

2. This addendum provides theory of operation, maintenance instructions, a parts list, and diagrams for switching power supply printed circuit board A7. This printed circuit board was used in some early units of the Model 4200. In later units, it was superseded by a conventional power supply printed circuit board.

3. DETAILED THEORY OF OPERATION.
(See Figure 1.)

4. The power supply printed circuit board performs the following functions:

a. Converts 100, 120, 220, 240 volt, 50 to 400 Hz, ac line power to +5.2, -5, +15, and -15 volt dc for system operation.

b. Develops regulated 5 volts dc for operation of its own circuits.

c. Generates a power-up signal for the microprocessor when supply voltage levels reach the proper values for system operation.

d. Activates an interrupt signal to the microprocessor when supply voltages drop to levels too low for reliable operation.

5. Input ac line power is supplied to the primary of power transformer T1 of the main chassis through fuse F1, LINE switch S1, and a voltage-change printed circuit card. The voltage-change printed circuit card provides a convenient way for changing the primary winding connections of power transformer T1 to accommodate the various ac line voltages.

6. Power transformer T1 steps down the ac line voltage, and the secondary ac voltage is rectified by bridge rectifier CR1. The resulting dc is filtered by capacitors C1 and C2 to develop +13 volts dc from which all other system operating voltages are derived.

7. The +13 volts is supplied to voltage regulator IC1, which develops a regulated +5 volts for operation of the internal circuits of the power supply. The +13 volts is also applied to switching regulator IC3. During operation form the ac line, transistors Q1 and Q2 are held on by a positive dc voltage developed by rectifier CR4.

8. The main function of the +13-volts supply is to power step-up switching regulator IC3 to develop +17 volts to operate an inverter circuit. Integrated circuit IC3 contains a voltage reference, an error amplifier, an oscillator, a pulse-width modulator, a pulse-steering flip-flop, dual output switches, and current limiting and shutdown circuitry. It generates 40 kHz output pulses; voltage regulation is accomplished by adjusting the width of these pulses.

9. A regulated +5-volts reference is developed from the input +13 volts by the reference regulator. This +5 volts powers all other internal circuits of integrated circuit IC3. It is also applied to a voltage divider consisting of resistors R27 and R30 and potentiometer R28 to provide an adjustable reference voltage against which the output voltage of the integrated circuit can be compared. A 40 kHz oscillator generates pulses which clock a pulse-steering flip-flop, and a ramp signal of the same frequency is developed from the oscillator output by resistor R20 and capacitor C6. This ramp signal is applied to one input of a comparator; the second input to the comparator consists of a voltage determined by the output of an error amplifier and a current limiter. As the ramp voltage rises, a pulse is developed at the output of the comparator, beginning at the point where the ramp voltage equals the reference voltage. By varying the reference voltage level, the switchover point of the comparator along the ramp can be adjusted, thereby adjusting the output pulse width.

10. The output pulses developed by the comparator are supplied to two output switches through NOR gates that are controlled by the steering flip-flop. In this application, the two switches are parallel connected and control the conduction of transistor Q3. Through use of inductor L1, rectifier CR8, and capacitors C9 and C10, the output of transistor Q3 boosts the +13-volts supply to +17 volts. This +17 volts is applied to the inverter circuit. It is also sampled by voltage divider R17/R18, and this sample is compared with the reference voltage supplied from potentiometer R28 by the error amplifier in integrated circuit IC3. The error amplifier in integrated circuit IC3. The error amplifier adjusts the input level to the comparator, thereby adjusting the output pulse width and the average dc output value as required to maintain the preset voltage level.

11. The +17 volts powers an inverter circuit that develops ac from which all output regulated dc voltages of the power supply are derived. The output pulses of the oscillator in integrated circuit IC3 clock flip-flop IC5a, which steers oscillator pulses alternately to transistors Q8 and Q9

through gates IC4b and IC4c. Transistors Q8 and Q9 drive transistors Q10 and Q11, respectively, developing a push-pull 20 kHz signal across the primary of transformer T1 on the power supply printed circuit board. Separate secondary windings on transformer T1 develop ac voltages of approximately 17 and 7 volts. These ac voltages are rectified to develop +17, -17, +7, and -7 volts and these voltages drive regulators IC6, IC7, IC8, and IC9, respectively, to develop regulated dc output voltages of +15, -15, +5.2, and -5 volts. The +5.2-volts regulated supply is adjustable by means of potentiometer R48.

12. The output voltage of the +5.2-volts regulated supply is monitored by comparator A1d to develop a power-up signal on turn-on and an interrupt signal for undervoltage or power-down conditions. When the instrument is turned on, comparator A1d develops a positive output pulse when the output of the +5.2-volts regulated supply reaches a level approximately 150 mV below the nominal output voltage; the exact point is adjustable by means of potentiometer R42. The positive output pulse of comparator A1d clocks flip-flop IC5b to deactivate signal RESET to the microprocessor on the control printed circuit board. When the output voltage of the +5.2-volts regulated supply drops below the reliable usable level during operation of the instrument or during instrument shut-down, comparator A1d switches its output level to a logic low, thereby activating signal NMI to the microprocessor. The microprocessor then activates signal HALT, which resets flip-flop IC5b, thereby latching signal RESET low to ensure resetting of the microprocessor to the start of its program.

13. TROUBLESHOOTING.

14. With normal input power applied to the instrument, check the power supply output voltages at each module power connector. Correct power supply voltages are shown on the applicable schematic diagrams. If an abnormal voltage is encountered, disconnect the module connector from the module and note whether or not the power supply output voltage becomes normal; if it does, the problem is probably not in the power supply but in the disconnected module. If, on the other hand, the abnormal voltage condition remains, work backward through the power supply circuits, comparing voltages and waveforms with those in Figure 2. By analyzing abnormal indications, it should be possible to localize the problem to one or more components of the power supply.

15. ADJUSTMENT.

16. With all power connections in place, the instrument controls set for line operation, and the correct line voltage applied, make power supply adjustments as follows:

NOTE

A digital voltmeter (3-½ digit) is required for power supply adjustment. All voltage measurements are referenced to common.

a. Remove the top and bottom covers from the instrument.

b. Connect the digital voltmeter to the center tap of transformer T1 on the power supply board potentiometer R28 for a reading of 17.5 ±0.1 volts dc.

c. Connect the digital voltmeter to pin 6 of connector P7 on the power supply board and adjust potentiometer R48 for a reading of 5.2000 ±0.002 volts dc.

d. Using the digital voltmeter, measure the dc voltage at pin 8 of integrated circuit A1 on the power supply board. The voltage should be approximately 2.5 volts. Add 0.150 volt to the measured value and record the result.

e. Using the digital voltmeter, measure the dc voltage at pin 9 of integrated circuit A1 on the power supply board. Adjust potentiometer R42 for a reading equal to the result obtained in step d ±0.01 volt.

f. Using the digital voltmeter, check to see that the dc voltages are within the specified limits:

Measurement Point	Voltage
Pin 5 of connector P7	+15 ±0.6 volts
Pin 4 of connector P7	-15 ±0.6 volts
Pin 3 of connector P7	-5 ±0.2 volts
Brown leadwire of connector P12	+5 ±0.2 volts

g. If any of the specified voltages cannot be obtained, troubleshoot the power supply board.

17. PARTS LIST.

18. Repair parts for the switching power supply board are listed on the following page.

19. DIAGRAMS.

20. See Figure 3 for the schematic and parts location diagrams for the switching power supply board.

TABLE OF REPLACEABLE PARTS

Reference	Description			BEC Part No.
POWER SUPPLY PC BOARD ASSEMBLY (A7)				
A1	Op. Amp.	LM339N	National Semiconductor	535018
C1	Capacitor, Elec.	4500 µF +75/-10% 25 V	GE 86F537M	283318
C2	Capacitor, Elec.	4500 µF +75/-10% 25 V	GE 86F537M	283318
C3	Capacitor, Tant.	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C4	Capacitor, Tant.	0.1 µF 20% 35 V	Sprague 196D104X0035HA1	283306
C5	Capacitor, Tant.	1 µF 10% 35 V	Sprague 196D105X9035HA1	283216
C6	Capacitor, PE	0.015 µF 10% 80 V	Sprague 192P1539R8	234094
C7	Capacitor, Tant.	0.47 µF 10% 35 V	Sprague 196D474X9035HA1	283324
C8	Capacitor, Tant.	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C9	Capacitor, Tant	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C10	Capacitor, Elec.	330 µF +50/-10% 25 V	Sprague 5030337F025PE	283330
C11	Capacitor, Tant.	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C12	Capacitor, Tant.	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C13	Capacitor, Elec.	1000 µF +50/-10% 10 V	Sprague 5030108F010PE	283329
C14 through C18	Capacitor, Tant.	6.8 µF 10% 35 V	Sprague 196D685X9035KA1	283217
C19	Capacitor, Cer.	22 pF 5% 200 V	Mepco 6183C0G220JA200	224217
C20	Capacitor, Cer.	3300 pF 10% 100 V	Kemet C052C332K1X5CA	224296
CR1	Diode, Bridge	VS-248	Varo	532014
CR2	Diode, Sil.	1N4001	Motorola	530151
CR3 through CR7	Diode, Sig.	1N914	T.I.	530058
CR8	Diode, Bridge	VSK-140	Varo	532022
CR9	Diode, Zener	1N5250 (20 V)	Motorola	530115
CR10	Diode, Sil.	1N4001	Motorola	530151
CR11	Diode, Zener	1N5259 (39 V)	Motorola	530085
CR12	Diode, Zener	1N5259 (39 V)	Motorola	530085
CR13 through CR20	Diode, Bridge	VSK-140	Varo	532022
CR21 through CR24	Diode, Sil.	1N4001	Motorola	530151
CR25	Diode, Sig.	1N914	T.I.	530058
IC1	Voltage Regulator	µA78MGUIC (Modified)	Fairchild	535058
IC2	Integrated Circuit	CD4011AE	RCA	534022
IC3	Voltage Regulator	SG3524N	Silicon General	535054
IC4	Integrated Circuit	CD4073BE	RCA	534216
IC5	Integrated Circuit	CD4013BE	RCA (ONLY)	534205
IC6	Voltage Regulator	µA78MGUIC (Modified)	Fairchild	535058
IC7	Voltage Regulator	µA79MGUIC (Modified)	Fairchild	535057
IC8	Voltage Regulator	µA78MGUIC (Modified)	Fairchild	535059
IC9	Voltage Regulator	µA79MGUIC (Modified)	Fairchild	535057
L1	Inductor	400 µH	Boonton Electronics	042176-1
Q1	Transistor, NPN	2N3904	Motorola	528071
Q2	Transistor, PNP	2N3906	Motorola	528076
Q3	Transistor, NPN	MJE-220	Motorola	528125
Q4	Not Used			
Q5	Not Used			
Q6	Transistor, NPN	2N3904	Motorola	528071
Q7	Transistor, PNP	MJE-230	Motorola	528126
Q8	Transistor, NPN	2N3904	Motorola	528071
Q9	Transistor, NPN	2N3904	Motorola	528071
Q10	Transistor, NPN	MJE-220	Motorola	528125
Q11	Transistor, NPN	MJE-220	Motorola	528125
R1 through R3	Resistor, Comp.	51 kΩ 5%	AB-EB	343468
R4	Not Used			
R5	Resistor, Comp.	5.1 MΩ 5%	AB-EB	343668
R6	Resistor, Comp.	5.1 MΩ 5%	AB-EB	343668
R7	Resistor, MF	24.9 kΩ 1%	RN55	341438
R8	Resistor, Comp.	10 kΩ 5%	AB-EB	343400
R9	Resistor, MF	84.5 kΩ 1%	RN55	341489
R10	Resistor, Comp.	10 kΩ 5%	AB-EB	343400
R11	Resistor, MF	24.9 kΩ 1%	RN55	341438
R12	Resistor, MF	5.11 kΩ 1%	RN55	341368
R13	Resistor, MF	93.1 kΩ 1%	RN55	341493
R14	Resistor, MF	5.11 kΩ 1%	RN55	341368
R15	Resistor, Comp.	200 kΩ 5%	AB-EB	343529
R16	Resistor, Comp	200 kΩ 5%	AB-EB	343529
R17	Resistor, MF	30.1 kΩ 1%	RN55	341446
R18	Resistor, MF	5.11 kΩ 1%	RN55	341368
R19	Resistor, Comp.	51 kΩ 5%	AB-EB	343468
R20	Resistor, MF	1.82 kΩ 1%	RN55	341325
R21	Resistor, Comp.	24 kΩ 5%	AB-EB	343437
R22	Resistor, Comp.	110 Ω 5%	AB-EB	343204
R23	Resistor Comp	100 Ω 5%	AB-EB	343200
R24	Not Used			
R25	Resistor, Comp.	51 kΩ 5%	AB-EB	343468
R26	Not Used			
R27	Resistor MF	4.02 kΩ 1%	RN55	341358
R28	Resistor, Var	1 kΩ 10% 0.5 W	Bourns 3329H-1-102	311404
R29	Not Used			
R30	Resistor, MF	4.02 kΩ 1%	RN55	341358
R31	Resistor, Comp.	1.2 kΩ 5%	AB-EB	343308
R32	Resistor, Comp.	100 Ω 5%	AB-EB	343200
R33	Resistor, WW	220 Ω 5% 2 W	Ohmite 42J220	310022
R34	Not Used			
R35	Resistor, Comp.	220 Ω 5%	AB-EB	343233
R36	Resistor, Comp.	220 Ω 5%	AB-EB	343233
R37	Resistor, Comp.	51 kΩ 5%	AB-EB	343468
R38	Resistor, Comp.	100 kΩ 5%	AB-EB	343500
R39	Resistor, Comp.	5.1 kΩ 5%	AB-EB	343368
R40	Resistor, Comp.	1 kΩ 5%	AB-EB	343300
R41	Resistor, MF	464 Ω 1%	RN55	341264
R42	Resistor, Var.	100 Ω 10% 0.5 W	Bourns 3329H-1-101	311406
R43	Resistor, MF	453 Ω 1%	RN55	341263
R44	Resistor, MF	10.0 kΩ 1%	RN55	341400
R45	Resistor, MF	4.99 kΩ 1%	RN55	341367
R46	Resistor, MF	12.7 kΩ 1%	RN55	341410
R47	Resistor, MF	2.21 kΩ 1%	RN55	341333
R48	Resistor, Var.	500 Ω 10% 0.5 W	Bourns 3329H-1-501	311405
R49	Resistor, MF	4.99 kΩ 1%	RN55	341367
R50	Resistor, MF	2.80 kΩ 1%	RN55	341343
R51	Resistor, MF	2.21 kΩ 1%	RN55	341333
R52	Resistor, Comp.	100 kΩ 5%	AB-EB	343500
R53	Resistor, Comp.	200 kΩ 5%	AB-EB	343529
R54	Resistor, Comp.	300 kΩ 5%	AB-EB	343246
T1	Transformer, Ass'y		Boonton Electronics	042175-1

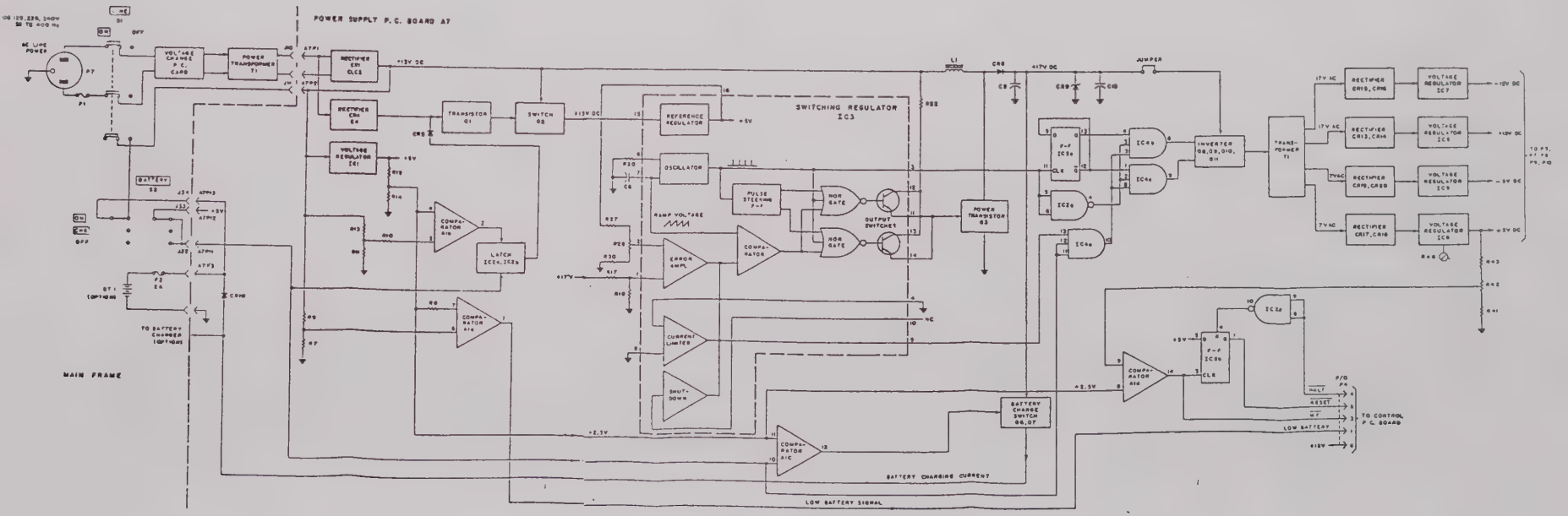


Figure 1. Switching Power Supply P.C. Board, Detailed Block Diagram

MEASUREMENT POINT	NORMAL VOLTAGE OR WAVEFORM	NOTES
A1, PIN 4	+2.5V	
A1, PIN 8	+2.5V	
A1, PIN 9	+2.65V	VARIES WITH SETTING OF R42
IC3, PIN 1	+2.5V	
IC3, PIN 16	+5.0V	
IC6, PIN 2	≈ +17V	
IC7, PIN 4	≈ -17V	
IC8, PIN 2	≈ +7V	
IC9, PIN 4	≈ 7V	
JUNCTION CR9 AND C10	≈ +17.4V	VARIES WITH SETTING OF R28

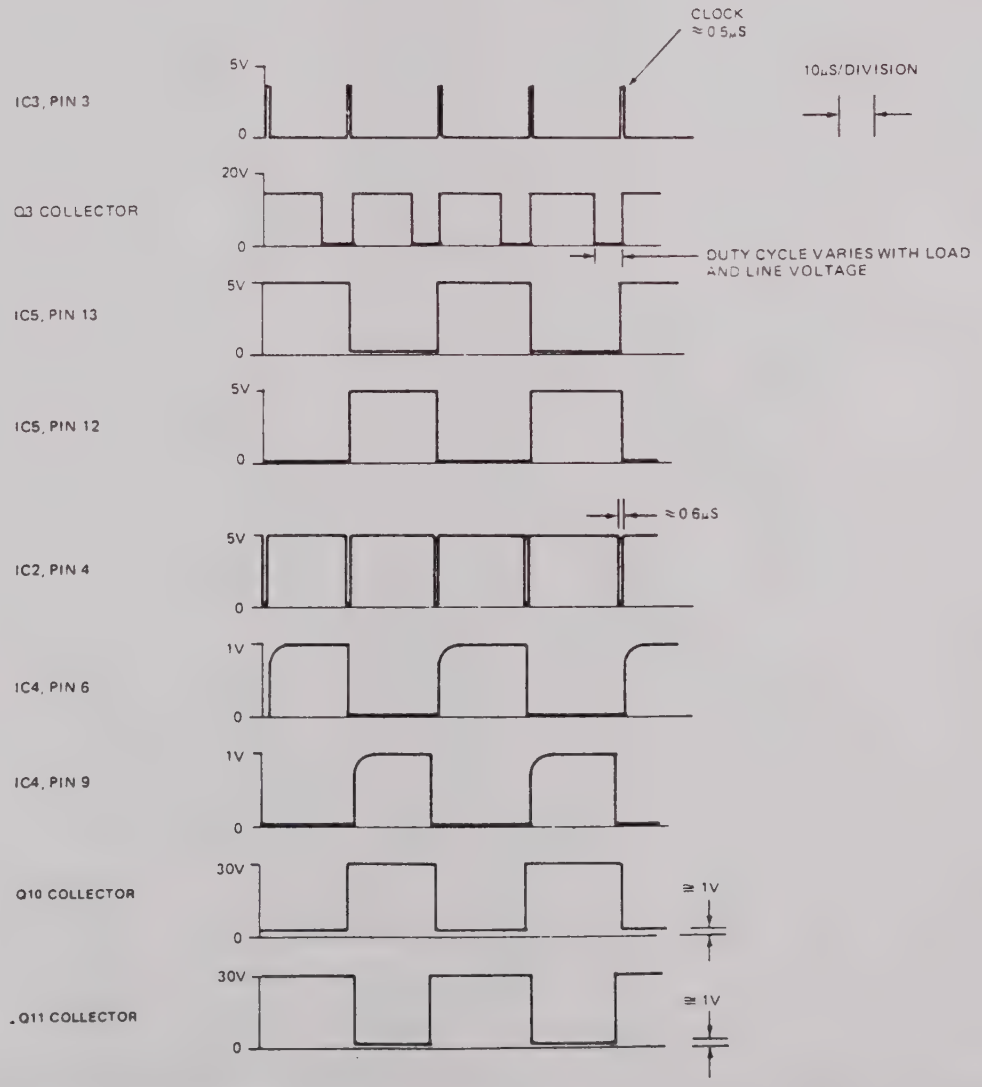
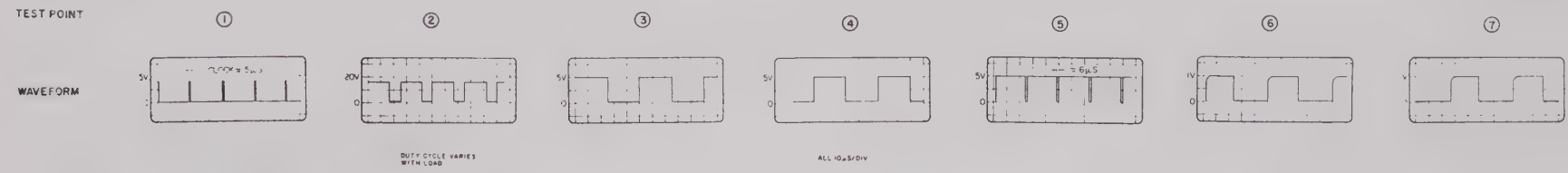
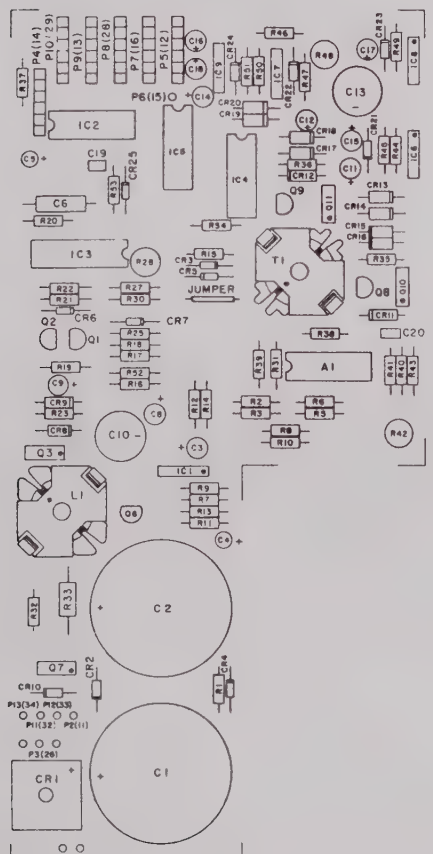


Figure 2. Switching Power Supply P.C. Board, Voltage and Waveform Data

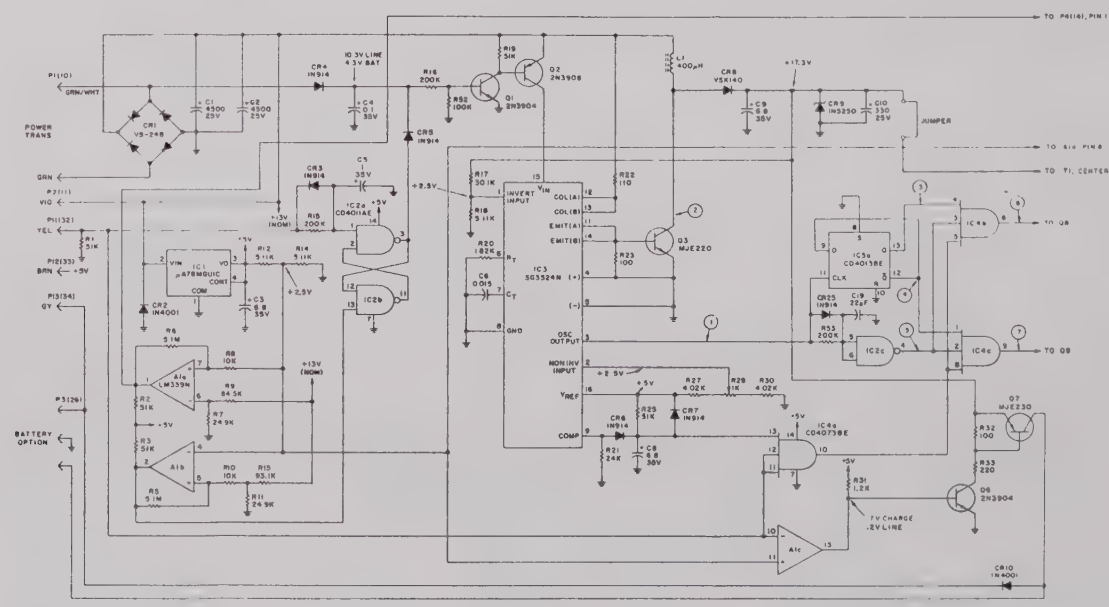


C831072G



E831053G

A7 POWER SUPPLY P.C. BD.



NOTES
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED
2. RESISTANCE VALUES IN OHMS
3. LAST NUMBERS USED: R53 C19 CR25 Q7 IC5
4. NUMBERS NOT USED: R4, R24, R26, R29 C7 Q4, Q8
5. ○ TEST POINT

P1(10) CONNECTS TO A1 W10 J10(10) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P2(11) CONNECTS TO A1 W11 J11(11) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P3(26) CONNECTS TO A24 W21 J112(8) ON FRAME SCHEMATIC 831074 SHT 1 OF 2

P11(32) CONNECTS TO A1 W22 J32(32) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P12(33) CONNECTS TO A1 W23 J33(33) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

P13(34) CONNECTS TO A1 W24 J34(34) ON FRAME SCHEMATIC 831053 SHT 1 OF 7

Figure 3. Switching Power Supply P.C. Board A7, Schematic Diagram (Sheet 1 of 2)

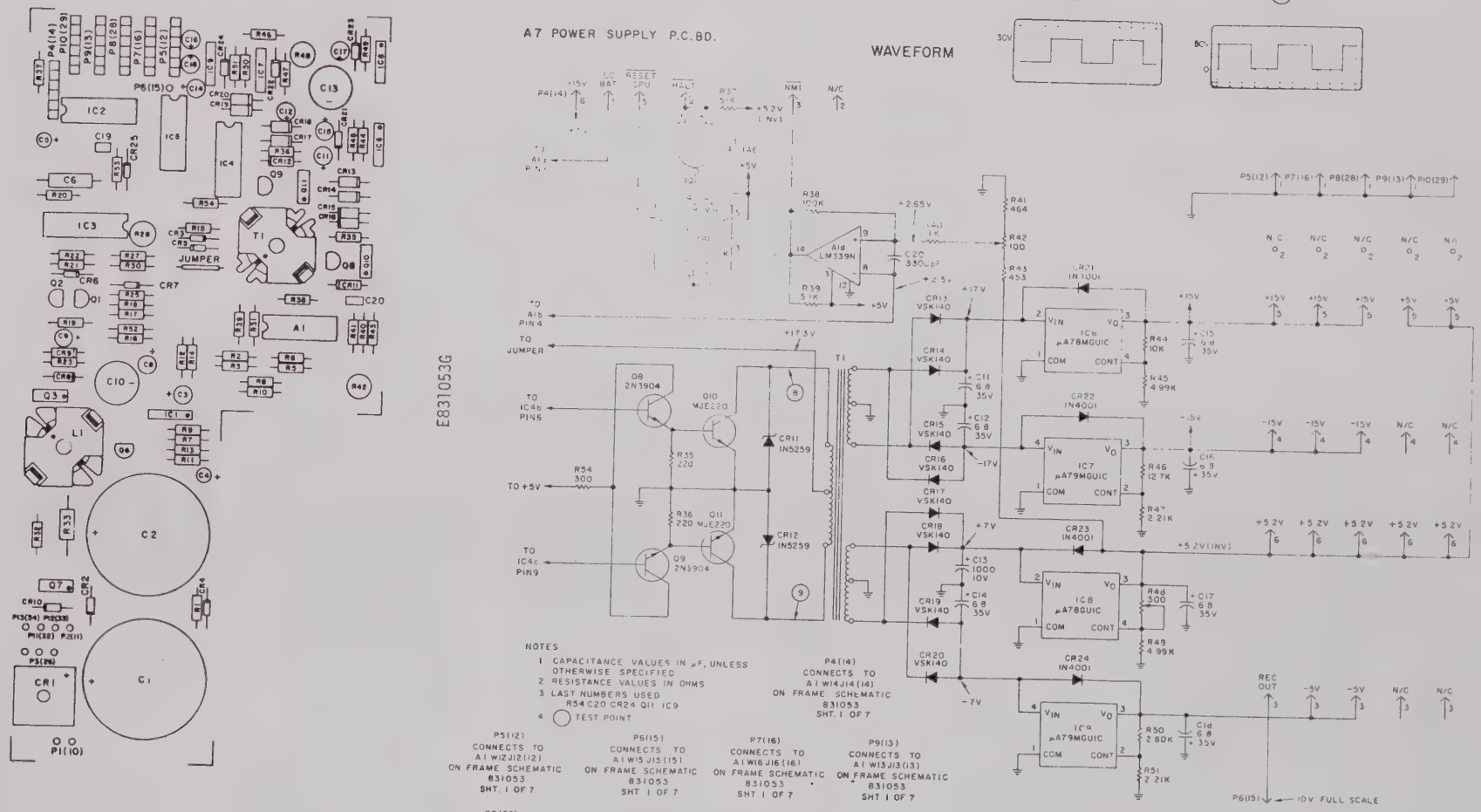

A7 POWER SUPPLY P.C.BD.
TEST POINT
WAVEFORM
E831053G
JUMPER
NOTES
1 CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED
2 RESISTANCE VALUES IN OHMS
3 LAST NUMBERS USED R54 C20 CR24 Q11 IC9
4 TEST POINT
P4(14) CONNECTS TO A1 W14J14(14) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P5(12) CONNECTS TO A1 W12J12(12) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P6(15) CONNECTS TO A1 W15J15(15) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P7(16) CONNECTS TO A1 W16J16(16) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P9(13) CONNECTS TO A1 W13J13(13) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P8(28) CONNECTS TO A1 W20J30(30) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P10(29) CONNECTS TO A1 W21J31(31) ON FRAME SCHEMATIC 831053 SHT. 1 OF 7
P6(15) 10V FULL SCALE

Figure 3. Switching Power Supply P.C. Board A7, Schematic Diagram (Sheet 2 of 2)

APPENDIX A
IEEE-488 BUS INTERFACE
OPTION 4200-01

A-1. DESCRIPTION.

A-2. The IEEE-488 (GPIB) bus interface option permits external control of the instrument and data capture by a wide variety of compatible controllers. The instrument may be operated with other GPIB-compatible devices to achieve specific test automation goals, with no specialized control interface requirements for proper electrical operation.

A-3. Although no standard GPIB interface data formats have yet been established, certain common practices are achieving de-facto standard status. These practices have been adhered to in the design of the 4200-01 option interface formats and delineators, thereby assuring the user of format compatibility with almost all controllers, including the least expensive controllers.

A-4. CAPABILITY.

A-5. Certain sub-sets of full GPIB functions are specified in the IEEE-488 standard. The 4200-01 option includes the following capabilities:

SH1	Source Handshake
AH1	Acceptor Handshake
T7	Basic Talker, Unaddress if MLA, No Serial Poll or Talk Only capability
L3	Basic Listener, Unaddress if MTA
SR0	No Service Request capability
RL2	Remote-Local capability except LL0
PP0	No Parallel Poll capability
DC0	No Device Clear capability
DT0	No Device Trigger capability

NOTE

MLA = My Listen Address
MTA = My Talk Address
LLO = Local Lockout

A-6. INSTALLATION AND REMOVAL.

A-7. Option 4200-01 consists of interface board A23. Electrical interconnections are shown in Figure 6-8. To install and remove the interface board, proceed as follows:

a. Turn off power to the instrument.

b. Remove the screw that secures the top cover of the instrument, and slide the top cover back and off.

c. Position the interface board in the instrument so that the mounting holes in the interface board line up with the mounting posts in the instrument.

d. Connect the flat cable connector in the instrument to the front edge connector of the interface board.

e. Connect the power cable near the rear of the interface board, observing polarity.

f. Attach the interface board to the mounting posts in the instrument using six 4-40 binder head screws.

g. Install the top cover of the instrument, and install the top cover screw removed in step a.

h. If required, remove the three screws that attach the rear panel cover plate of the instrument, and replace it with a new cover plate.

i. Reverse the procedures of steps a through g to remove the interface board from the instrument.

A-8. OPERATION.

A-9. Address Assignment. Before using the instrument on the GPIB, it must be assigned a unique address. This address is set using the five right-most sections of rear panel address switch S1 in accordance with table A-1.

TABLE A-1. ADDRESS ASSIGNMENT

Decimal Address	Talk Code	Listen Code	Switch Setting 5	4	3	2	1
0	@	SP	0	0	0	0	0
1	A	!	0	0	0	0	1
2	B	"	0	0	0	1	0
3	C	#	0	0	0	1	1
4	D	$	0	0	1	0	0
5	E	%	0	0	1	0	1
6	F	&	0	0	1	1	0
7	G	'	0	0	1	1	1
8	H	(	0	1	0	0	0
9	I	)	0	1	0	0	1
10	J	*	0	1	0	1	0
11	K	+	0	1	0	1	1
12	L	,	0	1	1	0	0
13	M	-	0	1	1	0	1
14	N	.	0	1	1	1	0
15	O	/	0	1	1	1	1
16	P	0	1	0	0	0	0
17	Q	1	1	0	0	0	1
18	R	2	1	0	0	1	0
19	S	3	1	0	0	1	1

TABLE A-1. ADDRESS ASSIGNMENT (Cont.)

Decimal Address	Talk Code	Listen Code	Switch Setting 5	4	3	2	1
20	T	4	1	0	1	0	0
21	U	5	1	0	1	0	1
22	V	6	1	0	1	1	0
23	W	7	1	0	1	1	1
24	X	8	1	1	0	0	0
25	Y	9	1	1	0	0	1
26	Z	:	1	1	0	1	0
27	[	;	1	1	0	1	1
28	\	<	1	1	1	0	0
29	]	=	1	1	1	0	1
30	Z^	>	1	1	1	1	0

Address 31 (11111) will not be recognized and should not be used.

A-10. Talk Only Mode Selection. The talk only mode is used to communicate with an output device such as a printer without using a controller. When the TALK ONLY section of rear panel switch S1 is set to the 1 position, the instrument will send the result of each measurement over the bus automatically. The receiving device must be configured to operate in this mode.

A-11. Listen Only Mode Selection. The listen only mode is included primarily for troubleshooting interface and programming problems; it has little utility in normal operation. When the LISTEN ONLY section of rear panel switch S1 is set to the 1 position, the instrument will be a listener for all data mode transmission.

A-12. Command Response. In addition to Talk and Listen Address commands, the instrument responds to the following:

a. **Addressed Commands (Responds if Listen Addressed).**

Mnemonic	Name	Function
GTL	Go To Local	Enables panel control
GET	Group Trigger	Hold current measurement

b. **Listen Address Group.**

Mnemonic	Name	Function
UNL	Unlisten	De-address as listener

c. **Talk Address Group.**

Mnemonic	Name	Function
UNT	Untalk	De-address as talker

d. **Unencoded Commands.**

Mnemonic	Name	Function
IFC	Interface Clear	Initialize interface
REN	Remote Enable	Permits remote operation

A-13. Operating States. The instrument operates in two separate states, whether in local or remote control. One state is the measurement state, during which the instrument performs and displays measurements; the other state is the data entry/recall state, which is operative during number entry or after recall of stored information. When operating on the bus, it is important to remember that the instrument can send only that information which appears on the front panel display.

a. **Measurement Mode Functions.** The following functions change the measurement mode of the instrument:

Keyname	GPIB	Function
PWR MODE	P	Display measured power
dB MODE	B	Display measured dBm or dBr
AUTO	A	Set autorange mode
HOLD	O	Set range hold mode

b. **Data Entry/Recall Functions.** These functions enable entry or retrieval of numeric constants used by the instrument. Operation reverts to the measuring state after data storage.

Keyname	GPIB	Function
LO LIMIT	L	Low limit value, in dB
HI LIMIT	H	High limit value, in dB
dB CAL FAC	D	Calibration factor constant, in dB
GHz	F	Interpolate frequency/ calibration factor table
SENS	S	Select sensor data tables
CHNL	N	Select channel number
dB REF	R	dB reference level for dB mode

c. **Special Functions.** Special functions include the automatic zeroing, automatic calibration, and clear functions.

Keyname	GPIB	Function
ZERO	Z	Initiates an automatic zeroing cycle
CAL	K	Performs 1 mW automatic calibration
CLEAR	C	Clear numeric entry to zero

d. **IEEE-488 Bus Command Extensions.** The following functions are added to bus operation:

Name	GPIB	Function
ADR. ZERO	Y	Zero selected ranges (0-6)
SET RANGE	G	Set to selected range (0-6)

These commands must be preceded by an appropriate argument. The argument for Y is the span of ranges to be zeroed; for example, 26 specifies zeroing ranges 2 through 6. If only one range is to be zeroed, the argument must begin and end with the same code (e.g., 11Y to zero only range 1). The argument for G is the range number (0 = 10 nW to 6 = 10 mW for 4200-4 sensors) to be set. From execution of the Y command to measurement mode, the

maximum time is as follows:

Command	Time
00Y	9.7 seconds
01Y	13.4 seconds
02Y	14.6 seconds
03Y	15.1 seconds
04Y	15.4 seconds
05Y	15.6 seconds
06Y	15.7 seconds

The "Y" command allows no wait time for a sensor to reach a stable zero before actual offset storage occurs.

NOTE

The G command sets the 4200 to an internal range which may not correspond to the range code output in the data string in Para. A-22. The table below relates internal and apparent range codes:

LEVEL		INTERNAL	APPARENT
+10 dB	1 mW	—	—
		6	
+6 dB	3.98 mW	—	
			6
0 dB	1 mW		—
		5	
			5
-10 dB	100 μW		—
-11 dB	79.4 μW	—	
			4
		4	
-20 dB	10 μW		—
-21 dB	7.94 μW	—	
			3
		3	
-30 dB	1 μW		—
-32 dB	631 nW	—	
			2
		2	
-40 dB	100 nW		—
-42 dB	63.1 nW	—	
			1
		1	
-50 dB	10 nW		—
-52 dB	6.31 nW	—	
			0
			↓
-60 dB	1 nW	0	
		↓	

A-14. REMOTE PROGRAMMING.

NOTE

It is assumed that the user is acquainted with GPIB principles and terminology. Refer to the controller instruction manual for the syntax needed to create specific bus commands and addressing sequences. All examples given apply to the HP 9825 calculator.

A-15. Bus Programming Syntax. The bus programming syntax mirrors the front panel keystroke sequence closely. Each key has been assigned an alphanumeric character, and sending that character is equivalent to pressing that front panel key. The resultant operation is indistinguishable from local control. Numerical values are translated by the GBIP interface so that commonly observed formats may be used. Fixed formats and floating point formats may both be used. These representations are converted to their equivalent fixed point values, and the sign information is post-fixed automatically, thereby ensuring that natural notations for numbers will be accepted by the instrument.

A-16. Suppose that it is desired to set the instrument to the PWR mode. The HP 9825 calculator could be programmed:

wrt 716, "P"

The "wrt" instructs the calculator to send data on the bus to one or more listeners. The number following is the address information; 7 is the calculator address, and 16 is the instrument address. (All examples in this appendix will use 16 as the instrument address, although any valid address can be assigned to the instrument.) When the calculator interprets the first part of the line, it will assert the ATN line to signify that commands or addresses will be sent on the bus. Following that, it will send three bytes or characters: Unlisten, the calculator Talk Address, and the instrument Listen Address. This information will configure both the calculator and the instrument for the data transfer. After the last command byte has been accepted, ATN will be released to the false state by the calculator. All information on the bus is interpreted as data in this mode. While in the data mode, the calculator will send the character "P" to the instrument. At the instrument, this will be interpreted as equivalent to pressing the MODE PWR key, and that function will be executed. Because there is no more data to be sent, the calculator will send a delimiter (the ASCII codes for Carriage Return and Line Feed). The instrument recognises the Line Feed as an end of message signal, and returns to the bus idle condition.

A-17. The preceding discussion of the sending of a single programming byte serves to illustrate two important points: every data transfer is preceded by a command/address preamble, and each transfer is terminated by a Line Feed character. In the preceding example, six characters were sent on the bus; only one was a programming byte.

A-18. The measurement mode functions (P, B, A, O) and the special functions (Z, K) do not expect any numeric value. These functions all execute as received. For example: the following will program dB and autorange mode:

wrt 716, "BA"
or
wrt 716, "AB"

Note that the sequence is unimportant, except that each function executes in the order it is received on the bus.

A-19. Suppose that the instrument is to be zeroed automatically, and then asked to send the reading in the

PWR and RANGE AUTO mode. The HP 9825 calculator could be instructed as follows:

```
wrt 716, "APZ"
red 716, V, S
```

The automatic zeroing cycle time is approximately 40 seconds. Until zeroing is completed, the instrument will be unable to respond with new data. The first line of the preceding instructions sets the operating mode and initiates the zeroing cycle. The last line reads the response from the instrument. The instrument response consists of two numeric values: the first value is the front panel reading, and the second is a status value (normally zero). These two numbers will be stored in the calculator variables (storage locations) V and S. Note that each data transmission from the instrument consists of two values. When the status value is non-zero, indicating an error condition, the data value will be set to zero. The program will normally test the status value to assure valid operating conditions.

A-20. Store/Recall Functions Syntax. The general syntax for store/recall functions is the same as the front panel sequence; if a numeric value immediately precedes the function, that value will be stored; otherwise, the existing stored value will be recalled to the front panel. These functions (L, H, D, F, S, N, R) thus operate in a dual mode.

A-21. Suppose that it is desired to store the current power level in dBm into the dBm reference so that all future readings will be referenced to the current value. Allowance must be made for the possibility that the current value is a dB relative value. To do this, the current dB value must be read, the existing dB reference must be recalled, the true dBm value must be computed, and this value must be stored into dB reference. The calculator could be instructed as follows:

```
red 716,V,S
wrt 716,"R"
red 716,X,S
V+X→Y
wrt 716,Y,"R"
```

Note that R is used twice in the program, the first time to obtain the existing value for the dB reference, and the second time to store the computed value. Also, note that the two read statements (red) each fetch a different value, the first value is the power value in dB, and the second is the dB reference.

A-22. Output Data Format. The data output of the instrument consists of two numeric values. The first is the numeric data in the display, and the second is the status information. The normal data output will have the following format:

```
abcsddddEsd,S,R(cr)(lf)
```

Where:

ab = mode (power in milliwatts = PW; dB = DM; dBr = DR)
c = channel (A = 1; B = 2; C = 3)
s = sign (+ or -)
dddd = data (four digits, each digit 0 - 9)
Esd = exponent, sign, digit
, = data delimiter
S = status digit:
- 0 = no error
- 1 = entry too small
- 2 = entry too large
- 3 = measurement under range
- 4 = measurement over range
- 7 = channel 3 over/under range

R = Range Code, coded as follows:
- 0 = -50 dBm or 10 nW
- 1 = -40 dBm or 100 nW
- 2 = -30 dBm or 1 μW
- 3 = -20 dBm or 10 μW
- 4 = -10 dBm or 100 μW
- 5 = 0 dBm or 1 mW
- 6 = +10 dBm or 10 mW
- 7 = +20 dBm or 100 mW

cr = carriage return
lf = line feed

A-23. Typical Application. Suppose that it is desired to measure insertion loss or gain with an instrument equipped with option 4200-03, channel 2 measures incident power, and channel 1 measures output power. The program, shown below, will request reference conditions and wait for the user to set them up. Following establishment of the reference, the program will loop on insertion loss/gain measurements. Each measurement is triggered by the user. Zeroing is prompted in the local mode at the beginning of the program. Reading errors, should they occur, will be signalled by a double beep from the calculator; normal measurements will give a single beep. There will be one print line per measurement. The reference value is not printed in this example.

Program Variable Usage:

P : = power measurement value
R : = range value
S : = status value
Z : = dummy input for prompts

```
 0: cli 7                          /clear interface
 1: ent "zero chl,2",Z             /prompt for zeroing
 2: rem 7                          /enable remote
 3: wrt 716,                       /0 dBref, auto - set ch 3
   "INA0R2NA0R3N"
 4: ent "ref measure",Z            /prompt to set up ref
 5: red 716,P,S,R                  /read ref value, status
 6: if S>0;dsp "error',S;          /test status
   beep;gto 4
 7: wrt 716,"IN",P,"R3N"           /set chl dBref = P
 8: beep;ent "measure",Z           /prompt for measurement
 9: red 716,P,S,R                  /read measurement, status
10: if S>0;dsp "error",S;          /test status
```

```
beep;wait 100;gto8
11: prt P,"dB"; gto 8          /print measurement
12: end
```

A-24. The program in paragraph A-23 also measures reflection coefficient if channel 1 measures reflected power and channel 2 measures incident power. The reference conditions are established with a short at the test port of the directional coupler.

A-25. THEORY OF OPERATION.

A-26. General. Interface board A23 is a microprocessor-driven data interface which converts IEEE 488 bus compatible signals into control codes that operate the internal control bus of the instrument. It also converts instrument data into IEEE 488 compatible signals for use on the bus. All data transfers are handled by source and acceptor handshake protocols as defined by IEEE-488-1975.

A-27. Detailed Description. (See Figure A-1.) All data manipulation and IEEE 488 bus management are controlled by CPU IC3 on the instrument control board in conjunction with a micro-program stored in ROM IC1 on interface board A23. All data transfers are handled in parallel-to-parallel mode by register A23IC3. ROM A23IC1 is enabled by signal ROM-IF supplied from the control board. Port selection in register A23IC3 is controlled by address bits A0 and A1. Input signals $\overline{RD}$ (read), $\overline{WR}$ (write), and $\overline{CS}$ (chip select) to register A23IC3 are controlled by CPU IC3 on the instrument control board.

A-28. Port A of register A23IC3 operates with I/O selectors A23IC8 and A23IC9 and pull-up network A23IC12 for data in/out. Port B of register A23IC3 is used for mode selection and address setting; these functions are preset manually by means of bit switch A23S1. Port C of register A23IC3 is used for handshake controlling. Controller interface signals are defined as follows:

DAV	DATA VALID
NRFD	NOT READY FOR DATA
NDAC	NOT DATA ACCEPTED
ATN	ATTENTION
IFC	INTERFACE CLEAR
REN	REMOTE ENABLE
SRQ	SERVICE REQUEST
EOI	END OR IDENTIFY

A-29. When power is turned on, signals TALK and LISTEN are both set false by the software through gates A23IC6b and A23IC6c, respectively. (See Figure A-2.) When the associated controller sends commands, it sets

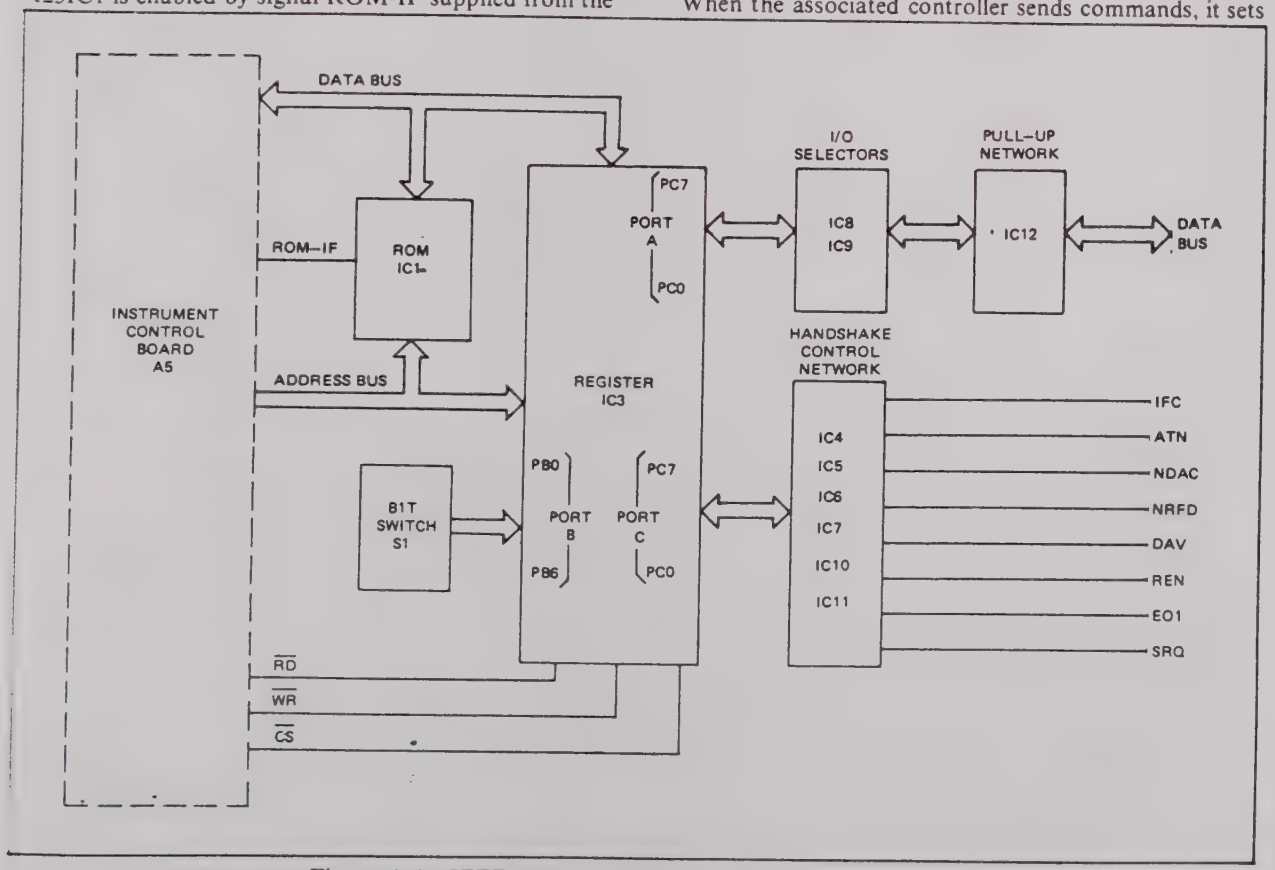


Figure A-1 IEEE 488 Bus Interface Option, Block Diagram

ment LED display will show 0011; if incorrect, it will show 000c.

r. Turn off power. Remove the test PROM from the PROM 0 socket on the control board. Reinstall PROM 0, PROM 1, and P5 on the control board, and PROM 2 on the interface board, observing orientation. Restore the address switch to its original settings.

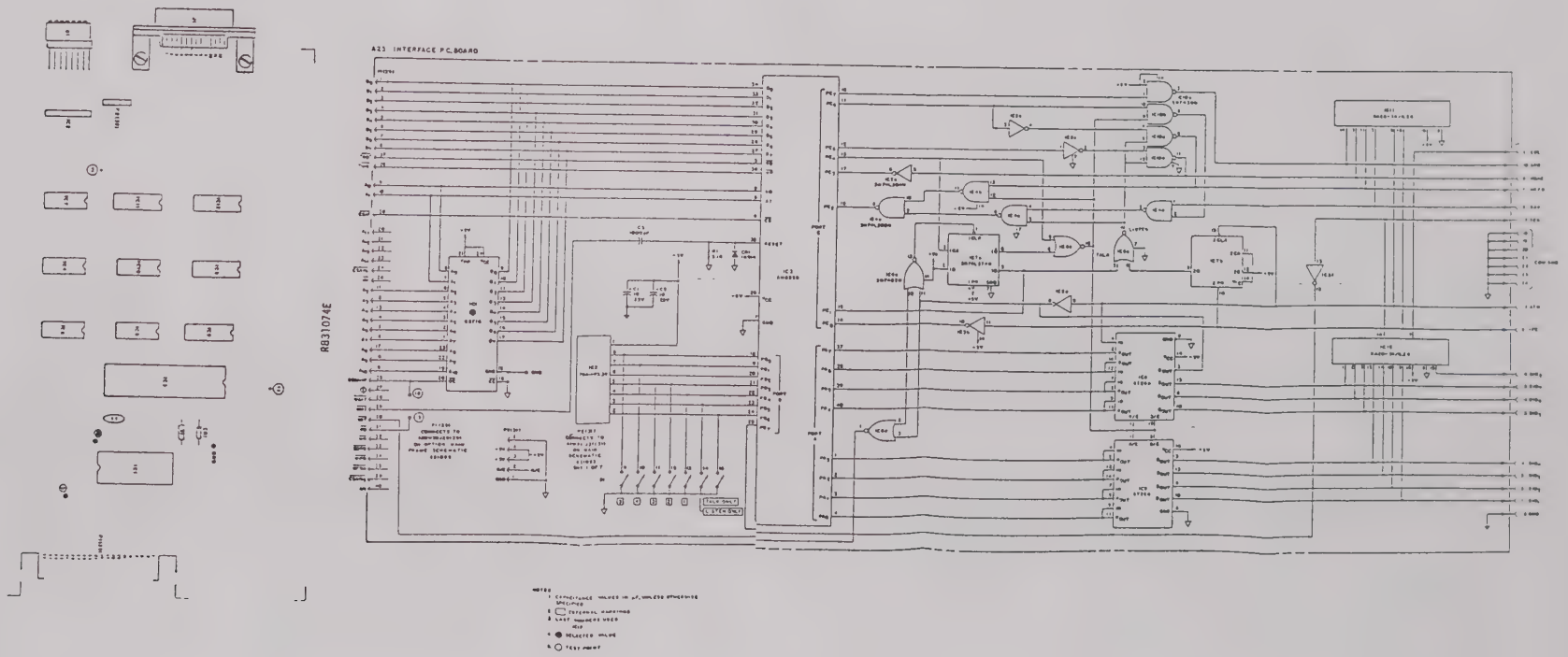


Figure A-2 Interface Board A23, Schematic Diagram

APPENDIX B
INPUT CHANNEL 2
OPTION 4200-03

B-1. DESCRIPTION.

B-2. Option 4200-03 provides an additional measurement channel (channel 2) that is completely similar to channel 1 except for mounting and input connector location. The input SENSOR connector for this channel is mounted on the rear panel of the instrument. With this option installed, measurements may be made on each channel individually, or both channels can be monitored automatically and the difference in dB displayed. This option consists of an input module, complete with chopper, that connects to the 40 line bus and has its own power connector. Connections are shown in Figure 6-8.

B-3. INSTALLATION AND REMOVAL.

B-4. To install and remove the input channel 2 option, proceed as follows:

a. Turn the instrument bottom up. Remove the screw that secures the bottom cover, and slide the bottom cover back and off.

b. Remove the four black flat-head screws on each side that secure the side covers.

c. Using the two screws supplied, install the rear input connector at the left side of the rear panel.

d. Dress the cable from the rear input connector down the left side frame of the instrument (as viewed from the bottom of the instrument) and across the front sub panel. The cable will run below the module being installed.

e. Secure the cable grounding lug under the uppermost, right-most binder-head screw (6-32) in the front sub-panel.

f. Install the channel 2 input module, and secure it to the side frames of the instrument with the four screws supplied.

g. Remove the four corner screws that secure the channel 2 input module cover, and remove the cover.

h. Plug the chopper into the channel 2 input module, seating the chopper firmly.

i. Depending on the options specified at the time of instrument purchase, the front 40-pin ribbon cable connector for the channel 2 input module may already be installed in the instrument; if so, connect it to the front edge connector of the channel 2 input module. If it is not already installed, remove the present connector assembly and install the new assembly supplied with the input channel 2 option. Connector spacing on the ribbon cable is such that it can be installed only in the correct way. If no interface module (option 4200-01) is present in the instrument, there will be an unused connector in the upper right section of the instrument. Make sure that all connectors are fully engaged with their respective modules.

j. Connect the power cable supplied to the power supply (position 8) with the black lead on the right side (as viewed from the bottom of the instrument), and to the input module (rear) with the black lead on the right.

NOTE

Avoid reversal of the two ends of this cable; there is lead transposition.

k. Install the channel 2 input module cover that was removed in step g.

l. Install the side covers and the bottom cover removed in steps b and a.

m. To remove the channel 2 input module, reverse the above procedure.

B-5. OPERATION.

B-6. When option 4200-03 is installed, each of the two input channels may be operated with any of up to four sensors. Channel and sensor data entered through the keyboard are selected as a set; that is, once a channel selection followed by a sensor selection have been made, subsequent selection of that channel causes selection of that sensor automatically. Subsequent selection of that sensor through the keyboard, however, *does not* cause automatic selection of that channel. Sensor assignment to a particular channel can be changed at any time by selecting the channel through the keyboard, then making another sensor selection through the keyboard.

B-7. Channel 1 and channel 2 operating procedures are basically the same as those described in Section II of this manual. A channel 3 mode of operation may also be selected. In channel 3 mode, the input levels to channels 1 and 2 are both monitored, and the difference between the two inputs, in dB only, is displayed on the instrument LED display. The following parameters selected for channels 1 and 2 prior to selection of the channel 3 mode remain operative for channel 3 mode operation:

1. Autoranging or range hold (for each channel)
2. Limits (for each channel)
3. dB reference levels (for each channel)
4. Sensor selection
5. Zeroing
6. Calibration

B-8. When channel 3 mode has been selected, the following keys are inactive:

1. ZERO
2. CAL
3. MODE PWR
4. MODE dB (automatically in this mode)
5. dB LIMITS LO and dB LIMITS HI
6. dB REF LEVEL dB
7. CAL FACTOR dB

In channel 3 mode, the instrument does respond to a CAL FACTOR GHz key command, applying the stored calibration factor for each selected sensor for that frequency. The recorder output in channel 3 mode is a function of channel 1, dB only.

B-9. MAINTENANCE.

B-10. The procedures used to isolate malfunctions to the channel 2 input module are similar to those described for the channel 1 input module in Section IV. (Refer to paragraph 4-17b.) Signature analysis techniques are used to isolate defective parts on the channel 2 input module. For convenience, the signature analysis information for the channel 2 input module is included in Section IV. (Refer to Tables 4-16, 4-17, 4-18, 4-21, and 4-23.)

APPENDIX C
REAR INPUT
OPTION 4200-04

C-1. DESCRIPTION.

C-2. Rear input option 4200-04 provides a second power sensor connector on the rear panel for those applications where sensor connection to the rear of the instrument may be more convenient. The second power sensor connector is connected in parallel with the front panel SENSOR connector. (See Figure 6-8.)

C-3. OPERATION.

C-4. To operate an instrument equipped with the 4200-04 option, connect the power sensor cable to either the front panel or rear panel SENSOR connector, as desired, and affix the shield supplied with the option to the unused SENSOR connector. Then, proceed with operation as described in Section II of the basic manual.

NOTE

Do not attempt to use both SENSOR input connectors at the same time; use only one and make sure that the shield is affixed to the other.

signal ATN true. The true ATN signal resets flip-flop A23IC7b, and gates A23IC10a and A23IC10d are released for NRFD and NDAC signals.

A-30. If the interface board is addressed as a talker, a clock pulse is generated at pin 13 of register A23IC3. This clock pulse clocks flip-flop A23IC7a, the output of gate A23IC6b is set high, and gate A23IC10b is released for the DAV signal. If signal ATN or IFC is set true during talking, the output of gate A23IC6a is set low, flip-flop A23IC7a is ready, and signal TALK is set false by gate A23IC6b.

A-31. MAINTENANCE.

A-32. General. Signature analysis procedures to be used for checking of the contents of ROM A23IC1 are included in Section IV of the basic manual. (Refer to Table 4-7A or 4-7B.) Troubleshooting procedures for the remaining circuits on the interface board are provided in the following paragraphs.

A-33. Test Equipment Required. The following items of test equipment are required for troubleshooting the interface board:

a. Test PROM, Boonton Electronics Model 4200-01, part number 950005.

b. Test board, Hewlett Packard part number 59405-66503.

A-34. Test Procedure. Test the interface board as follows:

NOTE

It is assumed in the following procedures that the instrument being tested operates normally independent of the interface option.

a. Turn off power to the instrument.

b. Remove PROMs 0, 1, and jumper at J5 from the control board; remove PROM 2 from the interface board. Install test PROM Model 4200-01 in the socket vacated by PROM 0, observing orientation.

c. Turn on power to the instrument.

d. Connect the Hewlett Packard test board with the bus connector.

e. Make the following connections on the interface board with jumpers:

1. Connect ATN to GND.
2. Connect NDAC to D101.
3. Connect DAV to D104.
4. Connect SRQ to D102.
5. Connect NRFD to D103.

f. Press the MODE PWR key. Operation of integrated circuits IC5d, IC6a, and IC7a will be tested. Correct operation is indicated by an indication of 0001 on the instrument LED display; incorrect operation by an indication of 000c.

g. Press the RANGE AUTO key. Operation of integrated circuits IC5e, IC10d, and IC9 will be tested. Correct operation is indicated by an indication of 0002 on the instrument LED display; incorrect operation by an indication of 000c.

h. Press the dB LIMITS LO key. Operation of integrated circuits IC10b and IC9, and integrated circuits IC4d, IC4c, IC4b, and IC4a will be tested. Correct operation is indicated by an indication of 0003 on the instrument LED display; incorrect operation by an indication of 000c.

i. Press the CAL FACTOR dB key. Operation of integrated circuits IC5c, IC10c, and IC9 will be tested. Correct operation is indicated by an indication of 0004 on the instrument LED display; incorrect operation by an indication of 000c.

j. Press the SELECT SENS key. Operation of integrated circuits IC10a and IC9 will be tested. Correct operation is indicated by an indication of 0005 on the instrument LED display; incorrect operation by an indication of 000c.

k. Remove the jumper connection between ATN and GND. Connect a jumper between ATN and D106 and connect a second jumper between REN and D105.

l. Press the dB REF LEVEL dB key. Operation of integrated circuits IC8 and IC5f will be tested. Correct operation is indicated by an indication of 0006 on the instrument LED display; incorrect operation by an indication of 000c.

m. Press the MODE dB key. Operation of integrated circuits IC8 and IC5b will be tested. Correct operation is indicated by an indication of 0007 on the instrument LED display; incorrect operation by an indication of 000c.

n. Press the RANGE HOLD key. Operation of integrated circuits IC4b, IC4a, and IC8 will be tested. Correct operation is indicated by an indication of 0008 on the instrument LED display; incorrect operation by an indication of 000c.

o. Press the dB LIMITS HI key. Operation of integrated circuits IC9 and IC5a will be tested. Correct operation is indicated by an indication of 0009 on the instrument LED display; incorrect operation by an indication of 000c.

NOTE

Note and record the setting of the address switch before performing the following steps. Restore the original address switch settings upon completion of the interface board tests.

p. Set the address switch to 0101010. Press the CAL FACTOR GHz key. If operation is correct, the instrument LED display will show 0010; if incorrect, it will show 000c.

q. Set the address switch to 1010101. Press the SELECT CHNL key. If operation is correct, the instru-

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